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High Altitude and Its Effect on the Human Body. I§

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SUMMARY

This paper is a report of the experimental data, mainly physiologic, concerning high altitude flying (up to 40,000 feet) obtained during the last two years in the Laboratory for Research in Aviation Medicine of the Section on Metabolic Research of the Mayo Clinic. The work has centered in the main around two subjects (1) anoxia (insufficient oxygen) caused by low barometric pressure and practical methods of its prevention, and (2) the dangers of aeroembolism and methods of avoiding the same. Training methods for aviation personnel in these subjects, and the necessity therefore, have been mentioned briefly.

DURING the last five years, as the growth of aviation has been more and more rapid, physiologic and medical problems have developed, which are definitely dependent on and associated with the fact that man is no longer limited to the land and sea and that the military aviator soars in the air to a height of $7\frac{1}{2}$ miles; he now goes higher and goes longer distances at greater speed than any other living creature. Medical science, therefore, was confronted with innumerable new physiologic and medical problems and, as a result, two and a half years ago the Board of Governors of the Mayo Clinic in conjunction with the Mayo Foundation, University of Minnesota, established the Laboratory for Research in Aviation Medicine as part of the Section on Metabolic Research of the Mayo Clinic.

In this paper the authors present the results of their investigations* with the hope that they will prove of assistance in maintaining aviators, as human machines, functioning normally up to 35,000 feet and with little departure from normality up to 40,000 feet.

NECESSITY FOR A NORMAL SUPPLY OF OXYGEN TO PREVENT ALTITUDE SICKNESS

To keep the human machine working normally it must have an adequate and normal supply of oxygen delivered at an essentially normal partial pressure.† The effect of a decreasing pressure of oxygen on the human body is well illustrated in Figs. 1a to f, by photographs taken of a burning candle at barometric pressures corresponding to those at elevations of 1000, 5000, 10,000, 15,000, 20,000, and 25,000 feet. Obviously there is marked decrease in the size and brilliance of the flame at increasing altitudes. Not only does the brilliance become less with increasing altitude, but the flame itself becomes much weaker and therefore in greater danger of being blown out. This corresponds to the weakness of the human flame and the danger of sudden collapse at altitudes in the region of 20,000 feet.

It is absolutely necessary, therefore, to maintain a normal supply or partial pressure of oxygen in the lungs because the energy which runs the brain as well as the moving parts of this human machine is activated entirely by the burning or combustion of food by the oxygen carried by the blood stream to every cell of the body; therefore each cell, even those in the more distant parts of the body, must receive its regular supply of oxygen, and, what is more, the oxygen must be delivered to these cells essentially at the normal oxygen pressure. Unfortunately it is not sufficiently well realized that the effect produced by a decrease in the partial pressure of oxygen in the human body is a function of both time

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§ This article is being published in two parts. Part II will appear in the October issue of the Journal.

* For a general presentation of the subject and for reports of the extensive work done at Wright Field the reader is referred to reference 2.

† Gases are effective in the body, as in other chemical reactions, according to the gas pressure which they exert. When more than one gas is present, its fraction of the total pressure is referred to as its partial pressure. At all altitudes the air contains in round numbers 21 per cent oxygen, 78 per cent nitrogen, and 1 per cent of rare inert gases of which the chief is argon. It contains only traces of carbon dioxide, 0.03 per cent, which is the gas exhaled by the body as a result of combustion of food.

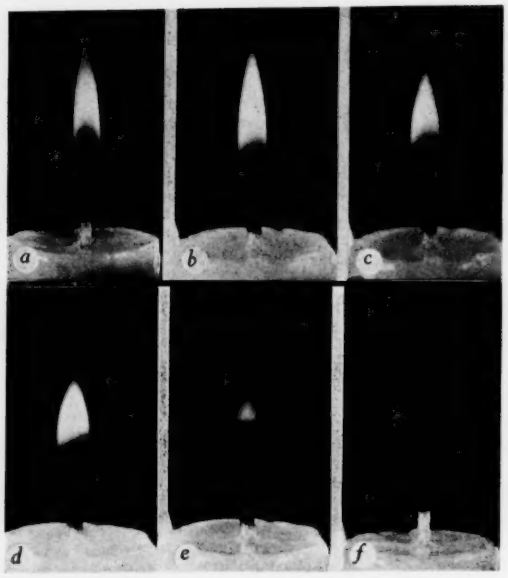

FIG. 1. Effect of decreasing barometric pressure on the brilliance and strength of the flame of a burning candle at elevations corresponding to: a, 1000; b, 5000; c, 10,000; d, 15,000; e, 20,000; and f, 25,000 feet, respectively. With ascending elevations note decrease in both the brilliance and strength of the flame; at 25,000 feet (f) the flame is just able to burn, and went out before the barometric pressure was decreased to that corresponding to 26,000 feet.

and intensity. This point is illustrated by two examples:

(1) At 28,800 feet the barometric pressure is 238.1 mm., of which approximately 21 per cent or 50 mm. represents the partial pressure of oxygen in the outside air—*i.e.*, the air to be inspired. In the lungs, however, the air will contain 47 mm. of water vapor and 40 mm. of carbon dioxide as a result of absorption of 40 mm. of oxygen at an R.Q.* of 1.0 for utilization by the cells in combustion and (assuming no acclimatization or temporary compensation by increased respiration) the partial pressure of oxygen in the lungs, therefore, would theoretically be zero, calculated according to the formula which is given below. Of course, without previous acclimatization and training in how to breathe, the subject could live only a few minutes, even by excessive breathing.

(2) At 20,000 feet the barometric pressure is 349.1 mm. of which approximately 21 per cent or 73 mm. is the partial pressure of oxygen in the inspired air. In the lungs, provided the body had no means of compensating temporarily by breathing more deeply, the partial pressure of oxygen would be only about 23 mm.

* R.Q. = Respiratory quotient which is the ratio between the volume of carbon dioxide expired and the volume of oxygen inspired. The R.Q. varies, fundamentally, with the proportion of each type of food being burnt, fat having an R.Q. of 0.71, protein of 0.80, and carbohydrate of 1.00; however, for short periods of time, factors other than food may influence the observed R.Q.

calculated according to the formula which is given shortly. However, as shown by experiments in a low pressure chamber (Fig. 2), the body can compensate for a brief period by excessive breathing, and the oxygen can be raised to approximately 36 mm. (Fig. 3). The

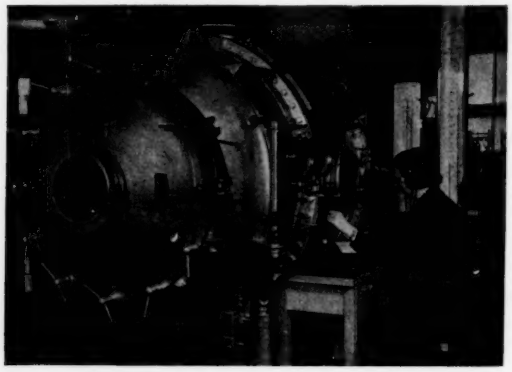

FIG. 2. A medium-sized low pressure chamber for research and training. It will hold six persons comfortably or three when one is lying down. The physiologic investigations at high altitudes reported in this paper were carried out in this chamber.

time element comes in at this point because one cannot compensate by increased breathing to this degree for more than fifteen to thirty minutes without development of fatigue and acapnia** with danger of cessation of respiration followed by death. Toward the end of the experiment the alveolar carbon dioxide, as shown by

** Acapnia is a condition of diminished carbon dioxide in the blood and is produced by hyperventilation (excessively deep and fast breathing). As carbon dioxide is one of the most important respiratory stimulants, normal automatic breathing is likely to stop suddenly if too much carbon dioxide is washed out of the blood.

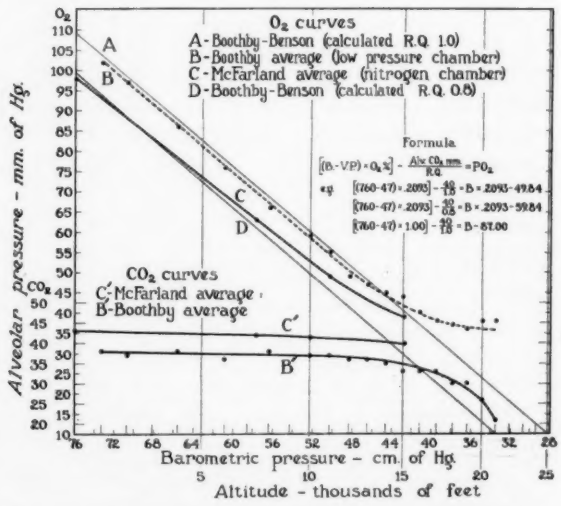

FIG. 3. Alveolar oxygen and carbon dioxide pressures at various altitudes while breathing air.

curve B (Fig. 3), is falling fast; this change indicates that the danger of acapnia is near.

The length of time an aviator can withstand anoxemia varies somewhat among normal individuals, and in the past the selection of aviators has been largely based on their ability to withstand anoxemia or lack of oxygen. Of course, an aviator in good condition can withstand the anoxemia caused by the low oxygen pressure found at 15,000 feet much longer (more than an hour) than at 20,000 feet (less than half an hour). The critical threshold for death of a normal unacclimatized man is between 20,000 and 23,000 feet. In fact, above 10,000 feet every increase in elevation amounting to 1000 feet shortens measurably the length of time the aviator can safely maintain his altitude. However the "ceiling" of most aviators in good condition does not vary more than a few thousand feet, and as the need for staying long periods of time at high altitudes today is greater than formerly there is little or no point in making the selection on this basis. It is far better, as will be pointed out in many places in this paper, to prevent anoxemia and never to subject the aviator to low concentrations of oxygen.

Fig. 3 shows how the partial pressure of oxygen in the alveolar air, *i.e.*, in the depths of the lungs, varies as the aviator ascends.

The theoretical partial pressure of oxygen in the alveoli of the lungs can be calculated by the formula:

$$(O_2)_p = [(B - \text{V.P.}) \times O_2] - (CO_2)_a/\text{R.Q.}$$

where $(O_2)_p$ = pressure of oxygen in alveoli of lungs
V.P. = vapor pressure saturation at body temperature (37°C.) = 47 mm.
B = barometric pressure
O_2 = relative concentration of oxygen in air = 0.21 or, more exactly, 0.2093
$(CO_2)_a$ = average pressure of carbon dioxide in alveoli of lungs = 40 mm.
R.Q. = respiratory quotient

and where all pressure values are expressed in millimeters of mercury.

Example: Breathing air with R.Q. of 1.0 at sea level

$$(O_2)_p = [(760 - 47) \times 0.21] - 40/1.0 = 109$$

In Fig. 3, curve A represents the theoretical curve whenever the subject is burning nothing but carbohydrate (R.Q. = 1.0) as happens for a short time after eating considerable amounts of sugar or candy, and curve D represents the theoretical curve for a respiratory quotient of 0.8 when he is burning more fat (R.Q. = 0.7) than carbohydrate. More oxygen is needed to oxidize to carbon dioxide and water a substance like a fat such as tripalmitin, ($C_{51}H_{98}O_6$), than a substance like carbohydrate (sugar) ($C_6H_{12}O_6$), because the former must have extra oxygen to unite not only with the carbon to form carbon dioxide, but also with the hydrogen to form water. Body reserves of carbohydrates are small as compared with normal reserves of fat; therefore, within an hour after eating, the R.Q. starts to approach that of fat and at the end of twelve hours will usually be around 0.8. Incidentally, these curves suggest that a high carbohydrate diet may add 1000 or 2000 feet to an aviator's ceiling; therefore, the possible advantages of supplying pilots and commercial airplane passengers with candy (hard candy or chocolate bars) as well as with gum should be considered.

The observations shown in curve B, Fig. 3, were carried out shortly after breakfast, at a time when the R.Q. would, on the average, fall between 0.9 and 1.0. This is to be contrasted with the results obtained by McFarland[1] and his associates, which are shown in curve C. His experiments were carried out under basal conditions; that is, without breakfast, and at least twelve hours after eating. Therefore the R.Q. of his subjects would average close to 0.8, and his results, curve C, were definitely lower than those given here (curve B) and were in close agreement with the theoretical curve D calculated for an R.Q. of 0.8. The possible influence of three other factors, however, must be considered in attempting to interpret the slight difference in level between the authors' data and those obtained by McFarland. One of these factors is that his experiments were carried out in Boston, at sea level, while those reported here were carried out on subjects acclimatized to an elevation of 1000 feet; a second factor, the influence of which has not yet been determined, is that McFarland used high nitrogen and low oxygen mixtures to simulate altitudes whereas the authors' experiments were actually carried out in a low pressure chamber; a third factor, which possibly accounts for evidence in his curve of a compensatory factor beginning at a lower level than in the authors' experiments is that apparently his subjects were "taken up" more slowly and that the time factor of a more prolonged exposure to an increased elevation played a role in producing an earlier recognizable compensation by increased rate and depth of respiration. The very fact that the uncompensated curve for R.Q. of 0.8 is lower may stimulate an earlier attempt at compensation and as the direction of the compensating curves in both experiments indicate, the final compensated partial oxygen pressure may be within practical limits identical for any R.Q.

It is important to note in Fig. 3 that the averages of the determination of the alveolar oxygen at ascending altitudes made in the low pressure chamber, curve B, correspond very closely to the theoretical curve A up to about 12,000 feet. Above this elevation the partial pressure of oxygen in the alveoli becomes increasingly higher than the theoretical curve; the latter is based on the assumption that the body does not compensate. However, the fact that there is a corresponding decrease in the alveolar carbon dioxide pressure, curve B′, indicates that the body actually is able to compensate to a certain limited degree by hyperventilation. A

similar tendency for the body to compensate is evident in the carbon dioxide curve in McFarland's data as shown by curve C'.

However, while the possible significance of the slight differences between the experimental data given here and those of McFarland have been stressed, it is important that the main facts brought out by the two series of experiments be not obscured; namely, (1) that both positively indicate a progressive and essentially similar decrease in alveolar oxygen pressure with ascending altitude; (2) that this relationship of barometric pressure to alveolar oxygen pressure is linear up to about 12,000 feet and that above this elevation physiologic compensation is evident. However, as both series of experiments were carried out with meticulous care under their respective conditions, it is, for the present at least, permissible to draw attention to the possible significance of the dissimilarity in the data from the two laboratories, especially as the magnitude of the divergence referred to seems to be in accord with theory, dependent on the differences in conditions.

The average alveolar oxygen pressure in the lungs can be increased definitely by slow deep breathing, as shown in Fig. 4 and the aviator's "ceiling" increased temporarily by as much as 1000 or 2000 feet. It must be observed, however, that the alveolar oxygen increases and alveolar carbon dioxide decreases with deeper respiration. The decrease in carbon dioxide is dangerous because through its effect on the hydrogen-ion concentration of the blood it is a direct respiratory stimulant and is the chief factor in rendering breathing automatic. When the alveolar carbon dioxide is decreased, if the aviator is absorbed in fighting he may forget to breathe voluntarily and become unconscious from lack of oxygen before there is an automatic stimulation of respiration by reaccumulation of carbon dioxide.

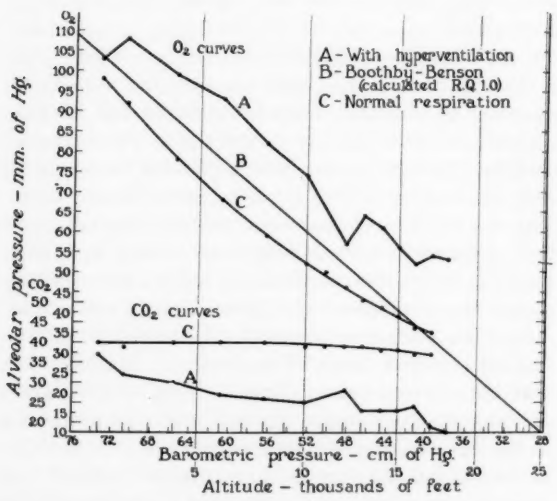
O_2 curves
A - With hyperventilation
B - Boothby - Benson (calculated R.Q 1.0)
C - Normal respiration
CO_2 curves
Alveolar pressure - mm. of Hg.
Barometric pressure - cm. of Hg.
Altitude - thousands of feet

FIG. 4. The effects of slow deep breathing of air as opposed to normal breathing on alveolar oxygen and carbon dioxide pressures at various altitudes.

Flying at or above 15,000 feet for any considerable time causes fatigue—more fatigue, increasing both with an increase in elevation and with an increase in length of time, than results from correspondingly severe mental and physical work at sea level. Even, as shown by Armstrong,[2] an altitude corresponding to 12,000 feet in a low pressure chamber, where there is no sense of fear or excitement, for several hours daily for several weeks causes subjects to become nervous and irritable. While aviators are well aware of the fact that an altitude of 18,000 feet and especially 20,000 feet causes rapid development of fatigue, for this fatigue becomes obvious even after a single comparatively short flight, they are, unfortunately, less well aware of the ill effects which develop more slowly and more insidiously at 12,000 and 15,000 feet. However, that is why pilots are permitted to fly only a certain small number of hours each month —many fewer hours than workers in other fields of equal responsibility are accustomed to perform with safety to all concerned. These short hours were established before facilities for administering oxygen efficiently were available, in an attempt to avoid the mental fatigue and exhaustion produced by lack of adequate oxygen pressure in the lungs and therefore in the brain and muscles that have caused some accidents commonly attributed to "pilot error." These accidents cannot any longer be considered solely pilot error but if they occur must now be blamed either to the lack of proper oxygen inhalation equipment and an adequate supply of oxygen for the use of the pilot and crew or to the reluctance* of crews through lack of proper training to use such equipment if available. The failure to use oxygen when flying above 10,000 feet may well shorten the active flying life of an aviator and may ground him many years earlier than would be necessary provided that (1) he always had an adequate supply of oxygen available, and (2) he always properly used such equipment.

Pilots and crews should not ascend to heights in excess of 15,000 feet (or in excess of 10,000 feet for more than short periods) without adequate oxygen equipment to maintain a normal pressure of oxygen in the lungs. It is now possible to ascend to 33,000 feet with proper equipment and *training* and to have an absolutely normal oxygen pressure in the lungs, brain and muscles. By the use of appropriate oxygen inhalation apparatus the rates of oxygen flow required are reasonable from the point of view of aviation economy. However, 30,000 feet is about the upper practical limit physiologically speaking for commercial aviation because of the danger of rapidly developing unconsciousness if the avi-

* It is hoped that shortly not only the aviation companies but the various government authorities concerned will issue definite rules and regulations concerning the use of oxygen by pilots and crews.

ator should remove the oxygen mask. An elevation of 40,000 feet is the upper practicable limit that can be attempted in military aviation even with the aid of the inhalation of absolutely pure oxygen, perfect equipment, and *advanced training*, because at altitudes above 33,000 feet the sum of the partial pressures of oxygen, carbon dioxide, and water vapor becomes the total pressure in the lungs and progressively and rapidly decreases below normal even if no air with its high (80 per cent) nitrogen content is permitted to leak in. Although the partial pressure of oxygen in the alveoli at an altitude of 40,000 feet, when pure oxygen is being breathed, corresponds to that at 11,000 feet when air is breathed, yet the altitude of 41,000 and especially of 42,000 feet is extremely dangerous as can be seen from the steepness of curve B (Fig. 5) because there is no leeway or margin of safety, and collapse and unconsciousness would develop rapidly at an elevation of 43,000 feet or even at 41,000 feet if a trace of air leaked in. Therefore to go to elevations in excess of 40,000 feet oxygen must be administered under positive pressure by means of a pressure suit. For the safety of all concerned no aviator at any time, whether as a pilot or as an observer, should exceed 15,000 feet without adequate oxygen equipment and training.

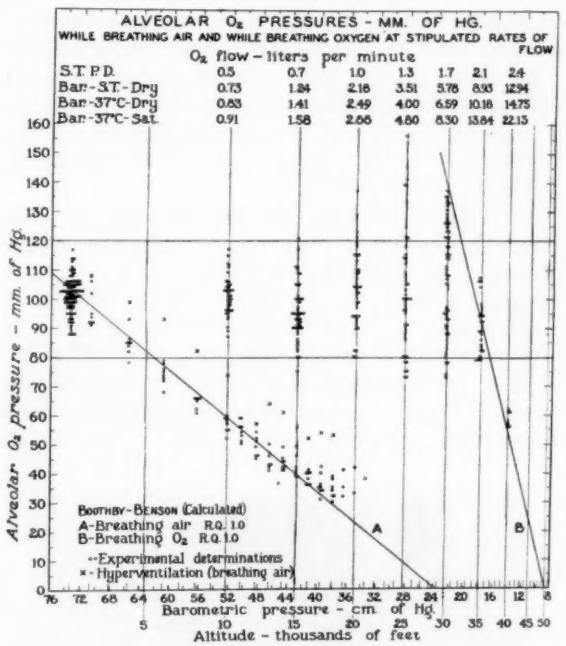
ALVEOLAR O_2 PRESSURES - MM. OF HG.
WHILE BREATHING AIR AND WHILE BREATHING OXYGEN AT STIPULATED RATES OF FLOW
O_2 flow - liters per minute
S.T.P.D. 0.5 0.7 1.0 1.3 1.7 2.1 2.4
Bar.-S.T.-Dry 0.73 1.24 2.16 3.51 5.76 8.93 12.94
Bar.-37°C.-Dry 0.83 1.41 2.49 4.00 6.59 10.18 14.75
Bar.-37°C.-Sat. 0.91 1.58 2.66 4.60 8.30 13.84 22.13
Alveolar O_2 pressure - mm. of Hg
Boothby-Benson (Calculated)
A-Breathing air R.Q. 1.0
B-Breathing O_2 R.Q. 1.0
•-Experimental determinations
×-Hyperventilation (breathing air)
A
B
Barometric pressure - cm. of Hg
Altitude - thousands of feet

FIG. 5. Alveolar oxygen pressures. Series around curve A were obtained while breathing air. Series running horizontally were obtained while breathing oxygen at the rates of flow indicated at top of chart.

METHODS OF PREVENTING ANOXIA (OXYGEN INSUFFICIENCY)

There are three different principles on which methods of compensating for the decrease in partial pressure of oxygen at high altitudes may be based: (1) the supercharged cabin using air under pressure, (2) the closed circuit oxygen system, and (3) the open circuit oxygen system.

Supercharged Cabin. Supercharged cabins in which the air pressure inside is increased to 1 or more pounds per square inch above the external atmospheric pressure are, of course, ideal from all points of view for long distance land and transoceanic commercial flying. Such planes have been developed and proved commercially practical. Whether or not the extra construction weight (with loss of pay load) as well as increased cost of construction and maintenance can be reduced so that this method can be extensively used on small types of aircraft remains to be seen.

Closed Circuit System. The most economical principle for the administration of oxygen is, of course, the closed circuit system. By such a system is meant a closed, circuitous pipe line approximately 1 inch inside diameter, with an expansible chamber or bag of a capacity of not less than 5 liters for a single individual although this ratio would not have to be maintained for multiple units; a container for soda lime or similar substance for absorbing carbon dioxide; a circulating pump if the system is multiple, or a properly placed inspiratory-expiratory valve when the system is constructed for use by only one individual; and an absolutely airtight face mask. Large reducing valves and automatic controls must be furnished to regulate the supply of oxygen. Both in the laboratory and in level flying, this type of apparatus is particularly economical, as theoretically the total amount of oxygen needed should not exceed the amount of oxygen each individual actually burns, which is approximately 0.25 liter at standard temperature and pressure dry (S.T.P.D.) per minute for a pilot who is relatively inactive up to 0.7 liter (S.T.P.D.) per minute for an active member of the crew working or moving about in the plane.

The practical objection to the closed circuit system is that air can easily leak into the system around the mask or many other places causing a dangerous accumulation of nitrogen. For this reason the method is not used in commercial aviation and also has proved too dangerous for extensive military use. Furthermore, the economy in the use of oxygen is not as great in aviation as one would at first suspect from theory because of losses occurring during rapidly alternating ascent and descent. During descent the oxygen in the system will be compressed and the volume decreased, thus automatically activating the oxygen supply valves. On the following ascent, the oxygen would expand with the decrease in barometric pressure, and the oxygen would be lost through the escape or pressure safety valves. Rapid alternation of such procedure would be very wasteful of the oxygen reserves.

Open Circuit Apparatus. The other type of apparatus is known in the physiologic laboratories as an "open circuit apparatus:" that is, the air is inspired

with the addition of an appropriate amount of oxygen and then expired directly into the surrounding air with only a very small, incidental amount of rebreathing. In the open circuit type of apparatus no attempt is made to remove the carbon dioxide so that no more than a very small amount of the expired air with its enriched oxygen content can be used again.

However, such a system, to be economically of practical value in aviation or in clinical medicine for administration of oxygen, must contain a reservoir bag, in order to collect, save and have ready for use on the next inspiration, the oxygen that has been flowing from the tank during expiration. As the major part of the inspiratory phase of respiration is only from a third to a fifth of the respiratory cycle, it is obvious that unless such provision is made, only a third to a fifth of the oxygen supplied can be utilized. We wish to emphasize this point because many wonder about the necessity of a reservoir bag. Failure to use more than a third to a fifth of the oxygen flow is one of many reasons why the old-fashioned "pipestem" method was so inefficient and is now little used.

However, to prevent the accumulation of an excessive and unbearable amount of carbon dioxide in such a reservoir bag, one must use either a small bag with a capacity somewhat less than an average normal expiration (450 c.c.) or else prevent, by other rather complicated means, the expired air from entering a larger bag. This reservoir bag is preferably placed close to the mask. However, it can be placed at the end of a long corrugated rubber tube (1 inch in diameter) provided (1) that the bag does not exceed a capacity of 450 c.c., (2) that the fresh oxygen intake is led directly into the bag, and (3) that the automatic sponge rubber air regulator or expiratory valve is close to the mask. For most purposes, both in aviation and in therapy, it is preferable to have the bag attached directly to the mask.

B.L.B. Oxygen Inhalation Apparatus

As the original apparatus designed by Boothby, Lovelace, and Bulbulian[3, 4, 5, 7, 9] has been described elsewhere in detail, only the recent improvements will be mentioned here.[9] The chief of these is that a sponge rubber, automatic air regulator has been substituted for the rather complicated metal connecting-regulating device. At low altitudes mixtures of air and oxygen are used; at altitudes of more than 30,000 feet practically nothing but pure oxygen from the tank is used. By a proper setting of the oxygen flow the amount of additional air required is supplied automatically through the sponge rubber disc. The sponge rubber disc causes just sufficient resistance so that no appreciable air enters the bag on inspiration until the reservoir bag is completely collapsed; conversely no appreciable amount of air passes out through the sponge rubber disc until the reservoir bag is completely distended. After the bag is extended or distended completely the air passes through the sponge rubber disc with scarcely noticeable resistance.

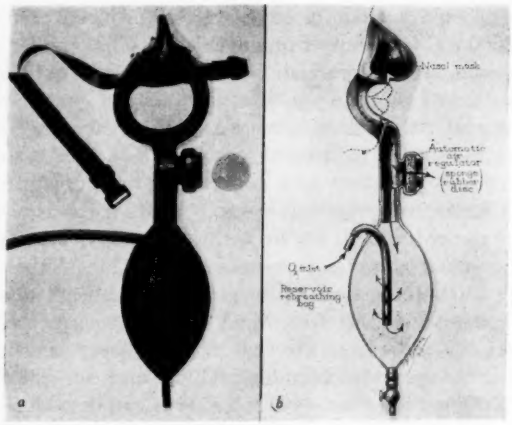

FIG. 6. Nasal type of B.L.B. oxygen inhalation apparatus for commercial aviation and for oxygen therapy; a, mask and bag; b, diagram showing direction of air current during breathing.

The nasal type of mask (Fig. 6a and b) with the mouth free for talking or eating is preferable for use on commercial airlines both for crew and passengers as the elevations to which they go rarely exceed 15,000 feet and at the most 20,000 feet.

For military aviation, the oronasal type of mask (Fig. 7) is preferable for two reasons: First, during the excitement of combat the flyer might need to breathe through his mouth, and second, he would often go to much greater altitudes (35,000 to 40,000 feet). In order to be able to use the radio microphone efficiently, a little turret was constructed directly opposite the mouth to hold the sponge rubber disc and against which the microphone may be closely applied. There is little

FIG. 7. Oronasal type of B.L.B. oxygen inhalation apparatus especially designed for military use at very high altitudes.

or no interference with the transmission of sound waves if the sponge rubber automatic air regulator is placed in a specially constructed groove at the outer end of the turret; in fact at high altitudes increased efficiency is obtained in part by exclusion of extraneous noise. Furthermore, this is an ideal situation for the sponge rubber disc because it is so close to the mouth that a greater part of the expired air with its moisture content will pass out through the sponge rubber without freezing even if the temperature is very low. In fact, tests have shown that not enough moisture will accumulate and freeze to render the apparatus inefficient in an hour even if the temperature is as low as −30°C. (−22°F.). This time can be prolonged by squeezing the turret and reservoir bag to "de-ice" them or break up any ice that may be collecting. In the military model, arctic rubber is used which will not become stiff for at least an hour at −40°C. (−40°F.); it is absolutely essential, of course, that the reservoir bag be made of rubber which maintains its flexibility at low temperatures.

Oxygen Requirement with Aviator Inactive and Active

In Fig. 5 two complete series of experiments are shown. The first series of data, which run downward to the right along curve A (which is the same as curve A in Fig. 3), represent the individual determinations composing the averages from which curve B, Fig. 3, was constructed, the significance of which has already been fully discussed. The second series of data (running horizontally) was obtained from the study of several subjects in the low pressure chamber at various altitudes when wearing the B.L.B. oxygen inhalation apparatus and when the rates of flow of oxygen supplied were as indicated at the top of the chart. These rates of flow are expressed (1) at S.T.P.D. (760 mm. 0°C. dry), (2) at the existing barometric pressure and 0°C., dry, (3) at existing barometric pressure and body temperature, dry, and (4) at the actual condition of the air as it is in the lungs at the existing barometric pressure (altitude) and saturated with moisture at the body temperature of 37°C. (98.6°F.).

The first method of expressing volume at S.T.P.D. is of particular value to the supply officer in order that he may readily calculate the amount of oxygen he must supply for a trip of given duration and at a given altitude; it also permits calculations of the amount which may be needed during possible variations of the original schedule. The fourth method is of physiologic interest in that it gives the volume that would be occupied by the oxygen in the lungs where it would be saturated with 47 mm. water vapor corresponding on the average to a body temperature of 37°C. (98.6°F.). The second and third methods of expression are given in order to show the magnitude of each factor that influences the volume of oxygen at different altitudes.

The experimental data show that the amounts of oxygen recommended by the authors are sufficient to maintain an essentially normal concentration of alveolar oxygen (between 80 and 120 mm.) for all elevations up to and including 35,000 feet, when the aviator is sitting and doing work comparable to operating a plane under normal air conditions. The experiments that show rather high results probably would be obtained in actual flight when running on the automatic pilot and the lower results, when the pilot is actually maneuvering the plane. Theoretically, when inhaling pure oxygen the aviator should have a normal alveolar oxygen pressure at 33,000 feet; the data show on the average that this is true and even up to 35,000 feet in no single experiment is the alveolar oxygen pressure below what it would be at 6000 feet without oxygen.

The data for 40,000 feet show that the alveolar oxygen pressure, in the few determinations there was opportunity to make, corresponds to an alveolar oxygen that would be obtained from a pilot breathing air without an additional supply of oxygen at 11,000 feet. In fact, the data are even slightly above the line representing the theoretical value for breathing pure oxygen. This is due to the fact that the subjects were able to compensate by increasing the rate and depth of respiration and thus to elevate slightly the average alveolar oxygen pressure. The entire series of experiments give definite proof of the efficiency of the B.L.B. oxygen inhalation apparatus.

In Fig. 5 as well as in earlier publications the authors specified only the rates of delivery of oxygen per minute for the pilot using the B.L.B. oxygen apparatus while sitting and maneuvering his plane under ordinary conditions, because that was the basic level which had to be established first and was especially important for civil aviation. In Table 1 there are indicated under the heading "Aviator, inactive" the minimal rates of oxygen flow needed by an aviator at various altitudes using the B.L.B. oxygen apparatus while sitting and piloting his plane with a minimal amount of muscular exertion; under these conditions, an aviator of average size would be consuming about 250 to 300 c.c. (S.T.P.D.) of oxygen per minute measured at standard temperature (0°C.) and pressure (760 mm.), dry. Under the heading "Aviator, active," is given the amount of oxygen needed for a pilot under conditions of rather difficult navigation or for a machine gunner firing but not doing a great deal of lifting or moving about; these degrees of work would roughly correspond to an oxygen consumption of 400 to 500 c.c. per minute (S.T.P.D.). Under the heading, "Aviator, very active" is given the amount of oxygen needed for a pilot or machine gunner working rather strenuously. This is estimated to be between 500 and 700 c.c. per minute (S.T.P.D.); this degree of work would correspond to that of a man walking at a rate of approximately 2 miles per hour. For each value as expressed at S.T.P.D. the value to which this amount of oxygen expands in the lungs of the aviator at each altitude is also given.

As far as the authors know, no measurements of oxy-

TABLE 1

Rates of Oxygen Flow Needed by Aviators at Various Elevations with Different Degrees of Activity when Wearing the B.L.B. Inhalation Apparatus

Actual Elevation (Thousand Feet)	Aviator, Inactive*		Aviator, Active†		Aviator, Very Active‡	
	Set oxygen flowmeter to correspond to:					
	Actual elevation§		5000 feet above actual elevation§		8000 feet above actual elevation§	
	Liters per min.		Liters per min.		Liters per min.	
	S.T.P.D.‖	In body	S.T.P.D.‖	In body	S.T.P.D.‖	In body
0 to 10	0.5	0.9	0.5	1.5	1.0	1.8
11 to 15	0.7	1.6	1.2	2.7	1.4	3.2
16 to 20	1.0	2.9	1.6	4.6	1.8	5.2
21 to 25	1.3	4.8	2.0	7.4	2.2	8.1
26 to 30	1.7	8.3	2.4	11.7	2.6	12.7
31 to 35	2.1	13.8	2.7	17.8	2.9	19.1
36 to 40	2.4	22.1	Dangerous		Dangerous	

* "Inactive": By this is meant that the pilot is sitting in his seat and flying the plane under ordinary atmospheric conditions.

† "Active": By this is meant as strenuous an amount of work as a pilot handling the plane in emergencies or a machine gunner actively firing.

‡ "Very active": By this is meant as strenuous an amount of work as can be performed in an airplane.

§ This setting refers to the Heidbrink type of kinetic flowmeter that has been calibrated according to the recommendations of Boothby and Lovelace. At these settings the actual amount delivered corresponds to the amount in the table. In the calibration of other types of flowmeters, these rates of flow should be conveniently indicated and calibrated for rates of flow indicated in the table by weight.

The columns under "Liters per min." headed "In body" indicate the volume of the oxygen after it has expanded to the condition in the lungs at body temperature (37°C.), saturated with moisture (47 mm.), and at the barometric pressure corresponding to actual altitude.

‖ S.T.P.D.: By this is meant standard temperature and pressure, dry.

gen consumption have been made under these varying conditions, especially under fighting conditions. Until such measurements are available the rates of oxygen consumption on which these rates of flow are based are entirely estimated except for the minimal requirements recommended for "Aviator, inactive." In military combat, however, the aviator should "play safe" and move his supply of oxygen up to or above the flow required for the maximal altitude that would be reached during combat. Immediately after combat, the pilot and crew members would reduce the rate of oxygen flow to that corresponding to their actual elevation in order to conserve their supply for future needs.

In considering the quantity of oxygen needed by the body in aviation it is important to note that mental activity, fright, or excitement, as such, does not increase the oxygen requirement directly but only indirectly by increasing muscular activity or muscle tension. That is, the actual energy used in the mental processes by nerve or brain cells is not sufficiently large to be measured by the various forms of apparatus for measuring the energy transformations of man; the increased oxygen consumption sometimes observed under various conditions of excitement is due, therefore, to increased muscular activity and not to the activity of the nerve cells themselves.

(To be concluded in the October issue of the Journal. Cold and aeroembolism, parachute descent, physiologic and engineering observations, and the training of aviators will be taken up in that issue.)

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Maneuverability and Control Surface Strength Criteria for Large Airplanes

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SUMMARY

A method has been developed which makes possible the determination of the horizontal tail strength required by the basic flight envelope which governs the strength of the wings. The method involves only the use of simple wind-tunnel data. It is shown that the maneuvering tail loads can be obtained without reference to the effect of the trimming tab. The controllability in pitch should be sufficient to subject the airplane to the flight envelope load factor at any speed.

The controllability criterion for the vertical tail is that the critical control speed with flaps in the landing position should not exceed the landing speed, and with the flaps in the take-off position, should not exceed take-off speed. The strength of the vertical tail should be based upon the use of the tab angle for trim with engines inoperative, together with a maneuvering pedal force.

It is suggested that the airplane should not run out of aileron control at a higher speed than it runs out of rudder control. Rational load criteria for the ailerons have not been developed.

It must be realized that the methods presented are in a crude stage of development, and that much refinement will be necessary before they can be regarded as completely satisfactory. It is felt, however, that the general principles discussed will afford reasonable bases for maneuverability and maneuvering load criteria.

INTRODUCTION

THE improvement of the flying qualities of multi-engined transport airplanes is impeded by the absence of quantitative maneuverability and control criteria. Two current tendencies have exaggerated the need for these data: the rapid increase in the size of commercial aircraft until they are beyond the range of present experience, and the likelihood of widespread adoption of some form of power boost to supplement the pilot's strength in operating the controls. Furthermore, the limit of safe extrapolation of more or less empirical control strength criteria is being exceeded, and there is a demand that these criteria be placed upon a rational basis. Many authors have investigated these problems, and this paper is merely an application of well-known methods to design.

The subject is divided into three parts, dealing with horizontal tail, vertical tail, and ailerons. In each case certain aspects of the separate but very closely related problems of surface strength and maneuverability and control are considered.

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The author is indebted to E. C. Posner of the Lockheed Aircraft Corporation for his contributions to the section of this paper dealing with the vertical tail.

Methods presented in this paper are based on the interpretation of wind-tunnel data. Fortunately, such data will almost always be available at least in a preliminary form during the design stages of the large aircraft on which rational analyses are important.

There will be no attempt, of course, to make a complete analysis of the maneuverability and controllability of large airplanes. Instead, certain particular problems which are of current interest to designers will be discussed. Two definitions of maneuverability must be distinguished. The maximum attainable rate of change of attitude with distance or time is the customary meaning, but the pilot effort required to produce a given maneuver is considered to be of greater significance. The latter might better be called controllability, and attention will be focused on this quantity rather than on maneuverability in the usual sense.

Control surface loads may be classified roughly as those which occur in steady and in accelerated flight. Steady flight loads are for obvious reasons never critical. Accelerated flight loads may be subdivided into "balancing" and "maneuvering" loads. For the purpose of this paper, balancing control loads are defined as those in a flight condition in which the sum of the aerodynamic moments about the center of gravity is zero. Conversely, maneuvering loads correspond to a condition in which this sum is not zero. According to this definition, gust loads are classified as maneuvering loads. A balancing condition is thus distinguished by the fact that no forces exist which tend to produce *rotational* acceleration.

Balancing and gust loads are readily determined rationally, because they depend on easily measured airplane characteristics. Maneuvering loads, however, present a more difficult problem, as they depend on the behavior of the pilot.

There are several possible limitations to control surface maneuvering loads. Among these are:

(1) The ability of the pilot to apply torque to the movable portion of the control surfaces.

(2) The limit of the control movement together with limitations on the airplane speed.

(3) The ability of the pilot to recognize the severity of a maneuver resulting from a certain control deflection.

(4) The ability of the rest of the airplane structure to resist the loads imposed during maneuvers resulting from control deflection.

(5) The surface load resulting from the most severe maneuver that will ever be required of the airplane.

Because with power boost, the pilot can apply very large torques to the surfaces and because full control deflection at maximum speed gives extremely high loads, it becomes necessary with large aircraft to place more emphasis upon the fourth and fifth limitations.

All curves have been calculated for a conventional four-engined airplane of 40,000 pounds gross weight. Although the absolute magnitudes are of no particular significance, the general trends and relationships have been found to hold for airplanes of half and twice this size, and are believed to be of broad applicability.

The data are derived from $^1/_{12}$ scale wind-tunnel tests of a powered model.

Horizontal Tail

Maneuvering Strength

The familiar "V-g" diagram when replotted in the form shown in Fig. 1 and simplified, has been given the name "basic flight envelope," since for one weight it defines the range of flight conditions permitted. It may

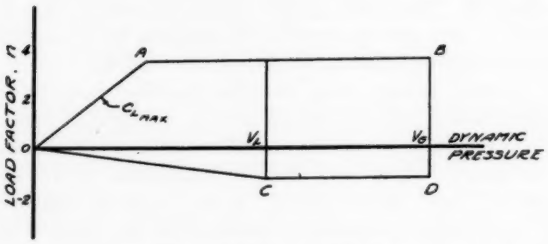

Fig. 1. Basic flight envelope.

be considered to be rather well established, and is the criterion for limiting the operation of the airplane by placards. The strengths of the wing and fuselage are made to conform to this diagram, but the tail has heretofore been limited to it only insofar as balancing loads are concerned.

The fundamental concept of this section is that the maneuvering strength of the horizontal tail should be just sufficient to subject the airplane to the load factors specified by the basic flight envelopes. The resulting design will then have consistent strength in its various components; the tail will withstand any pull-up which will not exceed the limit of the wing strength. The converse will not, however, be true. That is, the wings will not necessarily withstand any maneuver which the tail can apply.

The flight envelope limits the angle of attack at each air speed, and it is the existence of these limits which makes possible the rational determination of horizontal tail loads. Since no such clearly defined limits exist for the lateral and directional motion, criteria for the design of rudder and aileron are more difficult to establish.

It is then necessary to have an expression for the tail load required to subject the airplane to a certain load factor. This tail load will be divided into the initial balancing load, and the increment required to produce the pitching motion. An analysis similar to the following has been carried through by various authors.[1, 2, 5, etc.]

Consider the airplane balanced initially in level flight at the speed V. The equations which define the motion in the plane of symmetry under the influence of an increment of pitching moment ΔM may be written, using the operational form,

$$(D - X_u)u - wX_w - (X_q D - g\cos\theta_0)\theta = 0 \quad (1)$$

$$-uZ_u + (D - Z_w)w - (Z_q D - g\sin\theta_0 + VD)\theta = 0 \quad (2)$$

$$-uM_u - wM_w + (K_B{}^2 D^2 - M_q D)\theta = \Delta M/m \quad (3)$$

The motion has been referred to moving axes fixed in the airplane, and N.A.C.A. conventions and definitions have been employed. The derivatives have been divided by the mass so that they represent accelerations, thus:

$$M_w = (1/m)\, dM/dw$$
$$Z_q = (1/m) dZ/dq, \text{ etc.}$$

Eqs. (1), (2), and (3) express the equilibrium of horizontal, vertical, and rotational acceleration in terms of the variables u, w, and θ, which are, respectively, the incremental horizontal and vertical velocity and the angle of pitch.

Considerable simplification is realized by assuming that the velocity remains constant, since this eliminates not only the derivatives X_u, Z_u, and M_u, but also the necessity for the first equation. The derivative Z_q, which is principally due to the effective change in camber of the wing, is also neglected, because the term qZ_q has been found to be unimportant.

The assumption of constant velocity eliminates the "phugoid" or long period type of oscillation, whose existence depends upon the variation of velocity, leaving only the heavily damped short period motion. Now, since the period of the phugoid is of the order of magnitude of 40 seconds, and since the load factor will be found to reach its final value within a few seconds, it is apparent that the phugoid will not be of importance to the suddenly developed load factor. In other words, since the time required to reach the flight envelope is small, the velocity does not have time to vary enough to affect the results appreciably. Another consideration is that many "pull-ups" in transport operation occur in banked turns. In this case, only the increase in drag tends to reduce the velocity, the component of weight along the flight path being zero. Thus the assumption of constant velocity is even more nearly fulfilled.

The pitching moment increment ΔM specifies the manner in which the elevator is deflected. The pilot of a large airplane is concerned, however, with the rate

of response of the airplane and not with the way in which he is moving the elevator. It is, therefore, more reasonable to specify the airplane motion than the stick travel. The requirements that the maneuver be completed in a certain length of time and that a certain load factor is not exceeded are sufficient to keep the motion within rather close limits. There is the additional consideration that the pilot will be acquainted with the limit load factor, and whether he judges the acceleration by feel, by the angle of bank, or by a visual instrument, the only way in which he can reach that factor without exceeding it is by approaching it more or less asymptotically. For these reasons, the mathematically convenient expression suggested by R. T. Jones[5] is employed. The exact form specified is of little importance to the result if the restrictions mentioned are retained.

The expression for the load factor is, then,

$$n = 1 + \Delta n_0 \, (1 - e^{-at}) \tag{4}$$

The rapidity of the maneuver is regulated by the constant a. Using the relations $\Delta\alpha = w/V$, and $n = 1 + \Delta\alpha/\alpha_0$ the solution for ΔM becomes

$$\Delta M/m = -a \, \Delta n_0 \alpha_0 \, [K_B^2 \, (a + Z_w) + M_q] - \Delta\alpha[VM_w - (aK_B^2 + M_q) \, (a + Z_w)] \tag{5}$$

For a given airplane speed this expression is of the form,

$$\Delta M = K_1 + K_2 \, \Delta\alpha = K_1 + K_3 \, (1 - e^{-at})$$

Since ΔM defines the elevator deflection, the curve of elevator angle *vs.* time is of the same form.

Eqs. (4) and (5) are plotted in Fig. 2 and show the airplane motion and the required elevator operation.

It is to be noticed that in Eq. (5) there is a value of a which makes ΔM a maximum. This value is

$$a = -(Z_w + M_q/K_B^2)/2 \tag{6}$$

The corresponding maximum ΔM is:

$$(\Delta M/m)_{max.} = (\Delta P_t x_t/m)_{max.} = \frac{\Delta n_0 \alpha_0 (K_B^2 Z_w + M_q)^2 - \Delta\alpha \, (VM_w + (K_B^2 Z_w - M_q)^2}{(2K_B)^2} \tag{7}$$

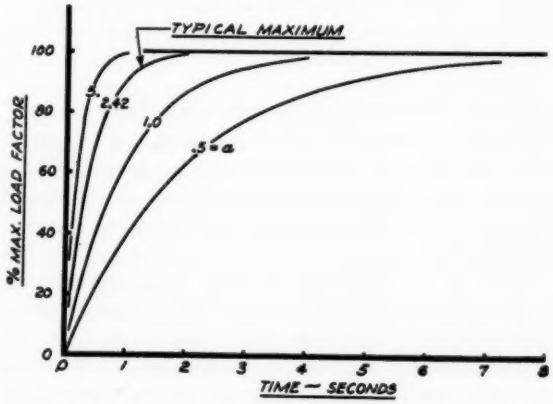

FIG. 2a. Time to pull-up to flight envelope.

The important physical significance of this maximum is that the airplane cannot be maneuvered (exponentially) faster than corresponds to the value of a specified by Eq. (6) without exceeding the limit load factor. Also, the maneuvering tail load increases as the rapidity of pull-up increases. If rapid reversal of the elevator motion is ruled out as an unreasonable operation for large aircraft, the increment in maneuvering tail load is virtually limited to that given by Eq. (7).

The maximum maneuvering tail load required to pull up to a load factor n_0 is, then, given by the sum of the balancing tail load and the increment obtained from Eq. (7).

The evaluation of ΔM from Eq. (7) is, fortunately, quite simple, involving the determination of the derivatives Z_w, M_w, and M_q and the radius of gyration, K_B. Z_w and M_w are measured directly in ordinary wind-tunnel tests. M_q can generally be taken as 1.25 times the damping due to the tail which is obtained from the analysis of tunnel tests.

The increment in pitching moment required of the tail is seen from Fig. 2 to consist of two parts, an instantaneously applied initial value and a subsequent increment which is exponential with respect to time but linear with angle of attack. The analysis of Eq. (7) is facilitated by transferring it to the pitching moment or static stability diagram (Fig. 3).

The stable curves shown are elevator effectiveness curves for the complete airplane; the unstable curve is for the airplane less tail. Consider that the airplane is flying steadily under the conditions described by point A, with the angle of attack α_A, the velocity V, and the elevator angle e_1. The angle of attack at the velocity V, corresponding to the flight-envelope load factor n_0, is that of point D, designated α_D.

In making a pull-up of limiting rapidity, the elevator motion must correspond to the curve of Fig. 2,

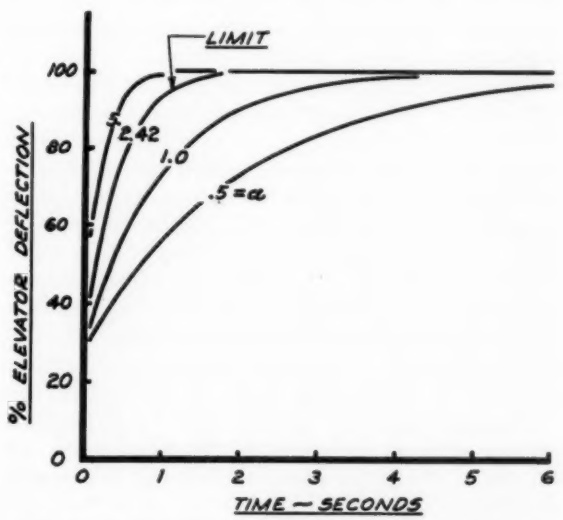

FIG. 2b. Typical elevator motion for exponential pull-up. **Note:** the proportions shown apply to one speed only.

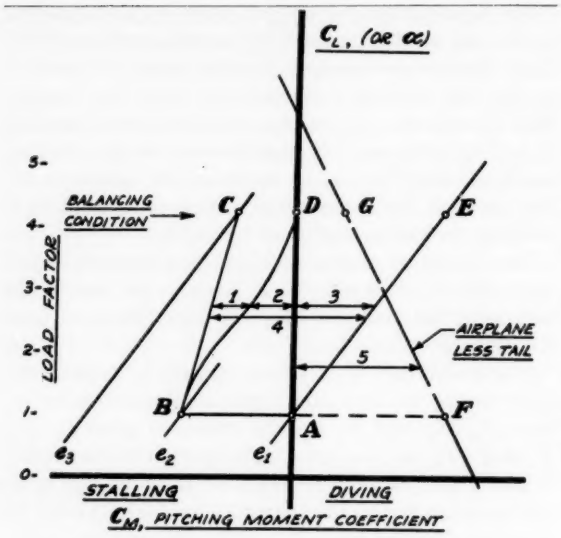

FIG. 3. Stability diagram (constant velocity).

marked "limit." This motion is transcribed to Fig. 3 with the aid of Eq. (7), and becomes path ABC. The elevator is thus deflected instantaneously from e_1 to e_2, and as the airplane responds to the pitching moment AB, the elevator continues to move to e_3. At any angle of attack, the various moments that make up the equilibrium expression (3) are represented on the diagram of Fig. 3. The stability term wM_w is the distance "3." The damping, which arises as soon as the airplane begins to move in pitch is the distance "1," and the moment due to the elevator motion is "4." The remainder, "2," is the accelerating moment which equals the angular inertia. At α_D, when the motion is complete, the elevator angle must be different from that required for static trim in order to overcome the damping. (As long as the load factor is greater than 1, the airplane is moving in a curved flight path, and damping in pitch exists.)

The total tail load is the sum of the "balancing" tail load, "5," Fig. 3, and the maneuvering increment, "1" + "2." Since the load "1" acts down on the tail as a portion of the maneuvering increment applied by the deflection of the elevator, and up on the tail as damping, the net tail load is the sum of "5" and "2." When the final load factor is attained, the angular accelerating moment, "2," disappears. The moment, CE, created by deflecting the elevator from e_1 to e_3 has been consumed by the stability moment DE and the damping, CD. The down tail load CG is partially offset by the up-damping load, CD, leaving only the "balancing" load, DG. Actually, since $1/5$ of the damping was assumed to be due to the airplane less tail, this much should be added to DG, but is generally negligible.

The total maneuvering tail load is almost invariably a maximum at α_0, so that the expression for the critical maneuvering increment of tail load is, from Eq. (7),

$$\Delta P_t = m\,\Delta n_0 \alpha_0\,(K_B^2 Z_w + M_q)^2/(2K_B)^2 x_t \qquad (8)$$

and is independent of the static stability. This corresponds to the moment AB in Fig. 3.

In order to obtain a quick preliminary check of the maneuvering tail load, it may be useful to have an expression for the tail load corresponding to instantaneous deflection of the elevator to the final angle, e_3, of Fig. 3. This expression is

$$\Delta M = (n_0 - 1)\,[-(MAC)\,WdC_M/dC_L - WM_q/V] \qquad (9)$$

The damping term may then be neglected, since even the remainder is considerably more severe than that given by Eq. (8). The motion that results from Eq. (9) is shown in Fig. 4. It is seen that the "limit" load factor is exceeded slightly before equilibrium is attained.

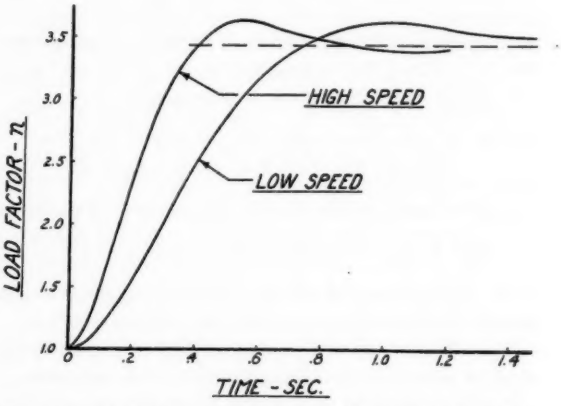

FIG. 4. Load factor resulting from sudden elevator displacement.

Finally, by traversing the periphery of the n *vs.* q diagram, determining at each critical point the sum of the increment in tail load given by Eq. (7) or (8) and the initial balancing load corresponding to "5" of Fig. 3, one is assured of a tail strength adequate to withstand any maneuver that the wings will stand. Careful inspection will generally make it necessary to check only two points, one for a positive and one for a negative load factor.

Chordwise Distribution of Horizontal Tail Load

It is of interest to be able to determine the approximate distribution of the maneuvering load over the elevator and stabilizer. This is easily accomplished with the aid of Fig. 3 and the customary wind-tunnel hinge moment data.

From the elevator effectiveness data, the elevator angle e_2, of Fig. 3, can be determined. Then the hinge moment corresponding to the maneuvering load becomes known. A number of references[3, 4, etc.] have indicated that this hinge moment can be triangularly distributed. Thus, the load on the elevator is known.

The difference between this and the total maneuvering load must be carried by the stabilizer, and can be distributed in an appropriate fashion.

A clue to the type of distribution on the stabilizer can be obtained from the tail load when the elevator angle is zero, which gives the angle of attack at the tail.

The distribution of the balancing tail load at α_D (Fig. 3) is of interest because it gives a picture of the effect of damping in producing a reverse load at the leading edge. The elevator load is obtained from the hinge moment corresponding to e_3, and acts downward in the case shown. The down tail load *CG*, part of which is the elevator load, is opposed by the up (damping) load *CD*, which has a peak at the leading edge. Adding these two leaves a down load on the elevator and rear spar, with a reverse load on the leading edge.

It should be noted that the tab setting has no influence on the magnitude of the maneuvering tail load. It only affects the hinge moment which must be applied by means of the control column to produce a given load, and to some extent, the chordwise distribution of that load. The control surface loading with deflected tab can be obtained directly from the hinge moment data by noting the increment in hinge moment due to the tab. The difference is then accounted for in the stabilizer load.

Maneuverability Criteria

The simplified method of determining the maneuvering tail loads given above makes possible a quantitative solution of one of the most difficult problems encountered in designing a power boost system. There is a great difference of opinion as to how much boost should be employed. It is apparent that the extent to which the required pilot forces are reduced by power boost strongly influences the maneuverability and stick force stability of the airplane.

In airplanes employing no boost, an elevator system has usually been designed so that it was possible for the pilot to apply sufficient force to the controls to get the tail down in landing. The maneuverability in pitch at speeds within the flight range was then accepted as whatever resulted from the control characteristics. With a power boost system, it is practical to provide hinge moments in excess of that required for landing, so that the controllability may be set by the designer at any desired value. The upper limit is the point where the stick force stability becomes too small. The question then arises as to what amount of controllability is desirable. It must be borne in mind that the horizontal surface loads are no longer affected by the hinge moment available.

Since the minimum radius of turn at a given speed is limited chiefly by the strength of the wing, or at low speeds by the maximum lift coefficient and the wing loading, the flight envelope defines a certain maximum maneuverability in pitch. This is only attainable, however, if the airplane can be pulled up to the limit load factor.

In Fig. 5 is plotted the stick force required to pull up to the flight envelope, assuming that the airplane is trimmed with zero stick force in level flight before the maneuver begins, with flaps up and with flaps in the approach position. For the case shown, the flight envelope corresponds to a 73° banked turn flaps up, and a 60° bank with approach flaps. The stick force for landing is also shown. The dotted portion of these curves corresponds to that portion of the flight envelope in which the load factor is limited by stalling of the wing. It is apparent from this figure that if the stick force for landing is quite heavy, the maneuverability throughout the speed range will be seriously limited. Some of the most delicate maneuvering in transport operation, aside from emergencies, occurs during approach before landing. At this time, the pilot is occupied with several duties and should be able to make sharp turns without excessive stick force. The criterion for maneuverability in pitch is, therefore, that during the approach, the stick force to pull up to the flight envelope should not exceed a moderate value, say 100 lbs. to 150 lbs. Also, it should be possible to pull up to the flight envelope at any speed without having to exceed the strength of one pilot.

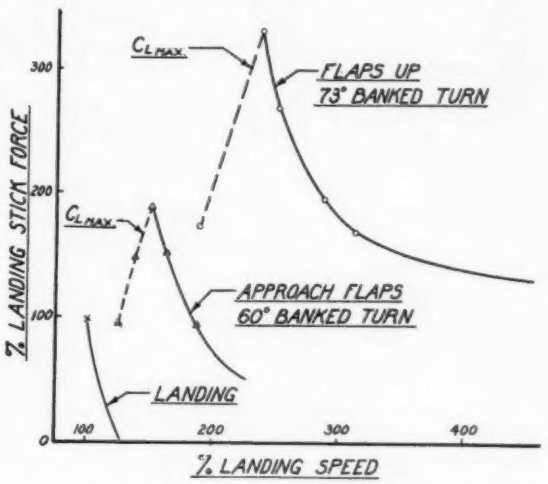

FIG. 5. Stick force for pitching maneuvers.

In determining the stick force required to pull up to a certain load factor, it is important to take into account the increment in elevator angle required to overcome the damping. This increment appeared as the moment *CD* in Fig. 3, and is easily calculated from the relation

$$\Delta M_D = (1 - n_0)\, WM_q/V = mqM_q \qquad (10)$$

in which ΔM_D is the final increment in pitching moment due to damping. It has been found that at low speeds this increment may require a 50 per cent increase in ele-

vator angle over the angle required for static trim at the same lift coefficient.

Vertical Tail

Maneuverability Criteria

The absence of any absolute limit on the angle of yaw renders more difficult the problem of determining rational maneuverability criteria for vertical surfaces. Consequently a good deal of judgment must be exercised by the designer.

On large multi-engined airplanes, it will be generally found that if satisfactory control is obtained, the resulting maneuverability will be adequate.

The most severe control requirement corresponds to the condition of flight in which sudden failure of one or more engines on one side of the plane of symmetry occurs.

If the pilot response is instantaneous, so that no appreciable yaw occurs before the unbalanced thrust is offset by rudder deflection, the condition can be studied statically. Dynamic effects always exist in practice, however, and their influence will be discussed later.

Both the reduced thrust and the increased rudder effectiveness at high speed tend to decrease the pedal force or the tab angle required to balance the airplane as the speed is increased, so that low speeds are always more severe.

The unsymmetrical slipstream action on the wings with engines inoperative gives rise to a rolling moment which must be balanced with the ailerons. In some arrangements, the rudder deflection also contributes to the roll, and often the ailerons contribute to the adverse yawing moment.

Fig. 6 shows the rudder force required to restore the airplane to neutral without the use of the tab, and the tab angle required without the use of the rudder pedal. The rapid decrease in rudder pedal force or tab angle as the airplane speed increases is noteworthy. Also, it is apparent that at some speed the rudder effectiveness becomes inadequate, and below this speed it is not possible to maintain rectilinear flight with no yaw. This speed is referred to as the critical rudder control speed. The critical aileron control speed is defined in an identical fashion.

The minimum flying speed can be lowered by permitting the airplane to yaw with the live engine forward, and balancing the side force with roll. If insufficient aileron control exists, the only recourse is to fly in a curved flight path or to throttle the live engines.

Critical control speeds are plotted in Figs. 7 and 8 for zero and 5° favorable yaw, together with normal landing and "best-obstacle-take-off" speeds. The latter is the speed which will give shortest take-off distance over a 50-foot obstacle. The best take-off flap setting was 60 per cent deflection. The reduction in rudder control speed with extended flaps is due to the loss in propulsive efficiency with flap extension, which amounts to 20 per cent for full flaps.

Operation with flaps full down and full power-on may occur near the landing speed in the event of an overshot approach or similar circumstance. Safety in the event of engine failure in this condition is necessary although the frequency of occurrence is not as great as the more usual take-off condition. The ultimate aim is to obtain critical control speeds below the landing speed when flaps are fully extended, and below the take-off speed when flaps are retracted or in the take-off position.

Figs. 7 and 8 show a comparison between critical

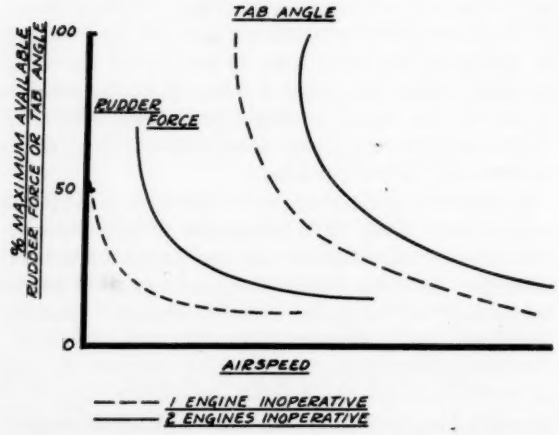

FIG. 6. Rudder force and tab angle for engine inoperative conditions. Flaps up; rated power; propellers on inoperative engines feathered.

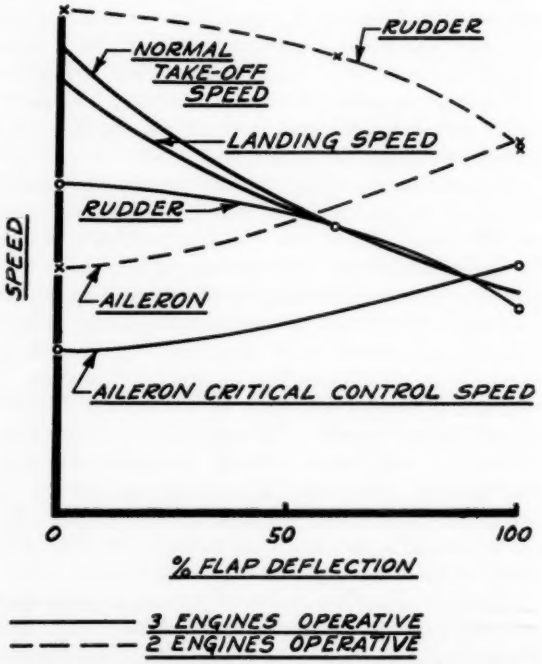

FIG. 7. Comparison of critical control speeds with take-off and landing speeds. Zero yaw; take-off power on operating engines; propellers idling on dead engines.

control speeds and power-off landing and normal take-off speeds. During take-off, failure of one engine is controllable without yaw, but it is necessary to permit 5° of yaw in order to control the sudden failure of both engines on one side at the instant of take-off. Three-engine climb is possible near the landing speed with full flaps provided the yaw does not become great. With both engines on one side of the airplane dead, the other two drawing take-off power and with flaps fully extended, the rolling moment is uncontrollable until the speed has increased considerably over the landing speed. This latter situation is not serious because of the compounding of emergencies involved. Two-engined airplanes in general are deficient in lateral control in the flaps-extended landing condition with power on one engine, yet only one accident due to this deficiency has come to the author's attention, and that was not in transport operation.

Low critical control speeds are obviously useless if excessive pedal forces are required. Therefore the controllability criterion suggested is that the critical rudder control speed should be limited by rudder effectiveness rather than hinge moment available. In other words, the pilot should be able by the application of a moderate rudder force to deflect the rudders completely at the *highest* critical control speed.

In the event of sudden engine failure, it will be impossible to prevent the airplane from yawing to some extent. In this yawed condition, the pedal force for a given rudder deflection is greater than at zero yaw, but the effectiveness is increased. It is not possible to draw the general conclusion, however, that a control system designed at zero yaw will be adequate to restore the airplane quickly to rectilinear flight at low speeds.

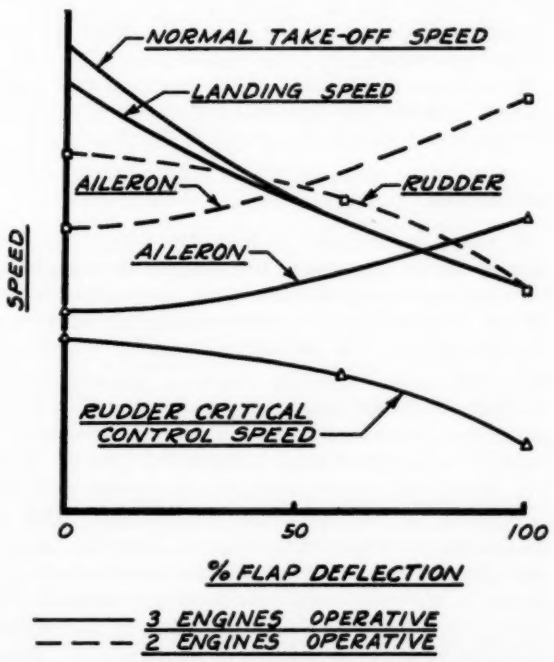

FIG. 8. Comparison of critical control speeds with take-off and landing speeds. 5° yaw; take-off power on operating engines; propellers idling on dead engines.

An exact analysis of the airplane motion after engine failure would involve assumptions regarding both the rudder and aileron operation. A representative picture of the behavior can be obtained readily by separating out the motion in yaw, assuming that the ailerons are used to provide enough roll to balance the side forces. Then the flight path is straight and the equation of motion is

$$I_z d^2\psi/dt^2 = \Delta N + (dN/dr)(d\psi/dt) + \psi dN/d\psi$$

in which N is the yawing moment, ψ is the angle of yaw, and r is the velocity in yaw. ΔN is the sum of the thrust moment and the rudder restoring moment.

The resulting motion is a damped oscillation with a period of several seconds. If, after engine failure, the pilot does not respond, but merely holds the rudders neutral, the airplane will eventually attain the equilibrium yaw angle given in Fig. 9, unless the inertia carries the airplane past the stalling angle of the vertical

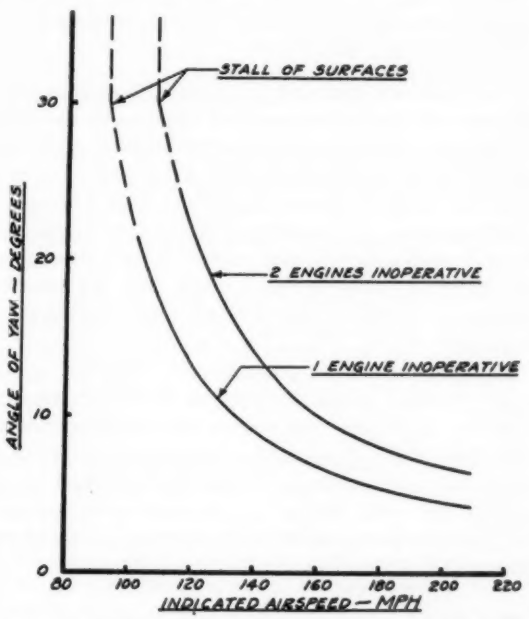

FIG. 9. Equilibrium yaw angle resulting from engine failure. Rudders neutral.

surfaces. This will only occur at low speeds. The actual motion is shown in Fig. 10, for the critical control speed and the high speed with two engines out. At the high speed, the yaw angle never exceeds the equilibrium angle by more than 4° even if the rudders are not used, but at low speeds, the motion would become uncontrolled unless stopped by the rudder even if the equilibrium yaw angle were below the stalling angle. The curves marked $r = 5°$ and $r = 27.5°$ correspond to sudden application of the rudder *angle* required for

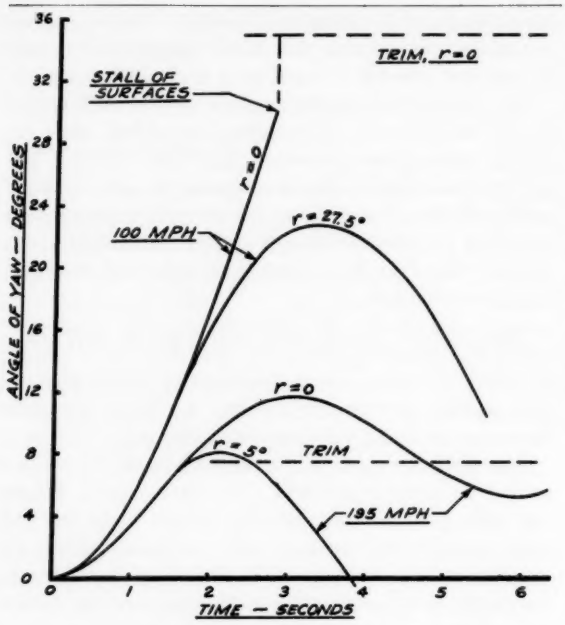

FIG. 10. Time history of yaw after engine failure. Two engines inoperative; rated power on operative engines; propellers idling on dead engines.

trim at zero yaw, a second and a half after failure of the engines. At the high speed this requires 75 lbs. while the airplane is at the maximum yaw angle attained, but only 25 lbs. by the time zero yaw is reached. The time required to reach neutral is so short that it would be hardly possible, and certainly unnecessary, to use both the tab and a large pedal force. At the low speed the forces are considerably greater, and the time for restoration longer, so that the tab would ordinarily be employed.

The importance of prompt pilot response in the event of engine failure during take-off is apparent from Fig. 10. If, in the case shown, the rudder deflection were delayed for $2^1/_2$ seconds, the surfaces could not be prevented from stalling. If the stalling angle of the vertical tail were reduced to the more usual value of 20°, pilot response would have to occur in about one second.

Load Criteria

It is apparent that the strength of the vertical surfaces must be sufficient to withstand loads imposed by the conditions discussed above. These loads can be determined rationally by the use of yawing moment data with the vertical tail removed and with it in place, together with rudder hinge moment data. Obviously, the yawing moment due to the vertical tail alone gives the total load on the surfaces and the hinge moment gives the chordwise distribution in a manner directly comparable to that used for the horizontal tail.

It has been seen that at high speeds, the rudder force and tab angle likely to be employed after engine failure are low, but increase with decreasing speed. Since either the rudder force or tab angle given by Fig. 6 is a minimum application of control, the necessary allowance for over-control may well be based on these values. In the light of the results of Fig. 10, it appears that a reasonable load would correspond to the use of tab for trim at zero yaw, supplemented by some multiple of the pedal force for trim at zero yaw, sufficient to cover the required force in the yawed attitude. This would require the use of full tab together with a large pedal force only at low speeds when engine failure is dangerous. It would be equivalent to using the maximum lift coefficient of the surfaces at a speed in the neighborhood of the "approach" speed, so that during take-off it would be impossible to exceed the strength of the vertical tail.

AILERONS

Controllability Criteria

Again in the case of the ailerons, maneuverability in roll is a difficult quantity to limit rationally and must, for the present, be left to the judgment of the designer.

The aileron controllability criteria are covered in the discussion of critical control speeds. Specifically, the ultimate aim is to reduce the highest aileron control speeds with full flaps to the landing speed, and with take-off flaps to the take-off speed. Lateral control becomes more severe as the flaps are deflected and as the airplane is permitted to yaw, but by careful balance of the several aerodynamic components, critical speeds approaching the landing speed can be attained even with all engines on one side of the plane of symmetry inoperative.

As with the rudders, it is also necessary that it be possible to deflect the ailerons completely at the highest critical control speed with a moderate wheel torque.

Load Criteria

It would be desirable to limit the strength of the ailerons by the strength of the wing in the same fashion that the strength of the horizontal tail is determined. This would seem to be possible since there is a definite limit to the angular acceleration which the wings can resist. Consider, however, the airplane in steady flight at high speed. If the ailerons are deflected slowly but continuously, the full deflection can be obtained if the required hinge moment is available. This will impose very severe loads on the ailerons, and the velocity in roll will eventually become high. Due to the gradual deflection of the ailerons, however, the acceleration in roll will not be large, and the loads imposed on the wings will remain small. Only if the ailerons are instantaneously deflected is any severe unsymmetrical inertia load placed on the wings. Thus, the required strength of the ailerons cannot be limited by the unsymmetrical wing strength. Because of these

circumstances, no load criteria are recommended in addition to the usual ones based on experience.

It may be possible to develop a rational aileron criterion by limiting the angle of roll to 90°, and the acceleration to that corresponding to the unsymmetrical loading for which the wings are designed. This has not been attempted.

Notation

m = airplane mass.
α = angle of attack.
α_0 = initial angle of attack.
n = load factor = $\Sigma Z/W$.
$\backslash n$ = increment in load factor = $\Delta n(t)$.
n_0 = $1 + \Delta n_0$ = limit flight envelope load factor.
g = acceleration due to gravity.
ΔM = increment of pitching moment due to tail.
ΔP_t = maneuvering increment of tail load.
K_B = radius of gyration about lateral axis.

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Book Reviews

Elementary Fluid Mechanics, by John K. Vennard; John Wiley and Sons, New York, 1940; 351 pages, $3.50.

This textbook is intended primarily for the beginner who knows the principles of mathematics and mechanics but has had no previous experience in fluid phenomena. It is based on the author's lecture notes, compiled during several years of teaching fluid mechanics at New York University.

Presentation of the subject matter begins with two chapters on fundamentals, physical properties, and fluid statics.

The flow of a frictionless fluid is taken up in Chapter III. This includes the Bernoulli and Euler equations, incompressible and compressible fluids, energy and impulse-momentum relationships, curvature, vortices, circulation, etc. As is inevitable in a book of this scope, certain of the equations must be accepted on faith. This is particularly true of the discussion of compressible fluids.

The flow of a viscous fluid is introduced in Chapter IV, in which laminar and turbulent flow in boundary layers, stability, and secondary flows are among the subjects discussed. There are a few points to which this reviewer objects. The fact that the only difference between the concepts of laminar and turbulent friction lies in the size of the fluid particles bringing about a transverse momentum exchange, and hence a shearing stress, is not brought out. When flow past obstacles is treated one of the streamlines is designated as a "discontinuity," whereas, actually, a relatively broad mixing region is present. Nowhere in the book are jets of a real fluid issuing into the same fluid taken up.

Chapter V is an excellent presentation of similarity and dimensional analysis, in which the various parameters are derived and discussed.

The next chapter deals with flow in pipes. A large amount of experimental data and the simpler theoretical concepts are given. Velocity distributions in laminar and turbulent flow, losses in pipe lines, bends, elbows, nozzles, valves, etc., are treated. There are two unfortunate omissions. The inlet length of a pipe and corner guide vanes are not taken up.

Chapter VII is a good presentation of flow in open channels. It includes discussions of the Chezy formula and coefficient, hydraulic cross-section, critical depth, hydraulic jump, and variable flow.

There follows a chapter on the instruments and techniques for fluid measurements. The various instruments and their characteristics are thoroughly described.

Flow about immersed bodies, that branch of fluid mechanics with which the aeronautical engineer is directly concerned, is taken up in Chapter IX. Good discussions of frictional and form drag, lift (circulation), and effects of finite aspect ratio are included.

Appendices give various tabular data, a derivation of the velocity of a pressure wave in a fluid, and a short description of cavitation.

The book is adequately illustrated and indexed and contains a long list of problems at the end of each chapter, as well as illustrative examples solved in the course of the presentation.

A. M. Kuethe

The Theory and Use of the Complex Variable, by S. L. Green; Pitman Publishing Corporation, New York, 1939; 136 pages, $3.00.

The author's previous book on aerodynamics was considered a scholarly treatment of the subject. The present volume takes up the mathematics necessary to an understanding of aerodynamic theory.

The chapter headings are: Complex Numbers and Their Representation; de Moivre's Theorem; Infinite Series—the Exponential, Logarithmic, Circular, and Hyperbolic Functions; Functions of a Complex Variable—Conjugate Functions—Cauchy's Theorem—Contour Integrals; Conformal Transformation; The Schwarz-Christoffel Transformation; Application to Potential Problems, and Application to the Theory of Alternating Currents. The Appendix lists suggestions for further reading.

This is an elegant and concise presentation of the fundamentals and use of the complex variable. A great deal of the material is written from the standpoint of the pure mathematician, giving an excellent foundation for the applications to hydrodynamics and electricity. Each chapter is followed by a list of exercises for the student.

Dimensionless Coefficients Applied to the Solution of Column Problems

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THE following analysis indicates that an enormous simplification in the handling of column problems can be effected through the use of the dimensionless coefficients described.

Consider, for example, dimensionless quantities α, β, θ, and γ defined as follows:

$$P/A = \alpha s;\ l/r = \beta(2\pi\sqrt{E}/s)$$

$$\theta = \pi\beta\sqrt{\alpha};\ \gamma = ec/r^2$$

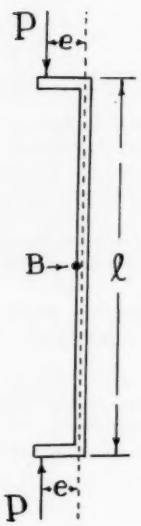

FIG. 1.

where s is the maximum compressive stress corresponding to the load P in Fig. 1; r is the radius of gyration of the cross-section area with respect to the axis of bending; c is the distance from the axis of bending to the point B at which this maximum compressive stress occurs.

Conclusions resulting from a study of the use of these coefficients include the following:

(A) The Euler equation:

$$\frac{P}{A} = \frac{\pi^2 E}{(l/r)^2}$$

reduces to

$$4\alpha\beta^2 = 1 \qquad (1)$$

(B) The generalized Johnson parabolic formula:

$$\frac{P}{A} = s - \frac{s^2(l/r)^2}{4\pi^2 E}$$

reduces to

$$\alpha + \beta^2 = 1 \qquad (2)$$

Plotted, the parabola passes through $\alpha = 1$, $\beta = 0$ and $\alpha = 0$, $\beta = 1$, becoming tangent to the Euler hyperbola $4\alpha\beta^2 = 1$ at $\alpha = 0.5$.

(C) Practically, paragraphs (A) and (B) mean that the information given in Table 10:4, page 297 ,Vol. 1, of reference 1, can be represented by Eqs. (1) and (2) with transition taking place at $\alpha = 0.5$, $\beta = 0.707$.

(D) For the column loaded as shown in Fig. 1, the relation between maximum compressive stress and load,

$$s = \frac{P}{A}\left[1 + \frac{ec}{r^2}\sec\left(\frac{1}{2}\sqrt{\frac{P}{A}}\sqrt{\frac{1}{E}}\frac{l}{r}\right)\right]$$

reduces to

$$\alpha[1 + \gamma\sec\theta] = 1 \qquad (3)$$

a dimensionless equation holding for all materials, equalized coplanar eccentricities, and slenderness ratios.

(E) In practical use, values of α, β, and γ will range between zero and unity.

(F) On page 37 of reference 2 are listed 19 linear equations, experimentally determined for aluminum alloys of widely varying yield strengths as given on page 23 of the same reference. Reduced to dimensionless form, these equations vary little from an average which can be expressed as:

$$\alpha + 0.9\beta - 0.1 = 1$$

while the most conservative equation can be written as:

$$\alpha + 0.85\beta = 1 \qquad (4)$$

(G) Assuming $E = 29{,}000{,}000$, $s = 30{,}400$, and safety factor $n = 1.90$, the common equation for structural steel:

$$P_w/A = 16{,}000 - 70l/r$$

reduces to Eq. (4).

(H) Assuming $E = 15{,}000{,}000$, $s = 16{,}200$, and $n = 1.80$, the common equation for gray cast iron:

$$P_w/A = 9000 - 40l/r$$

reduces to Eq. (4).

(I) The limit of usefulness of Eq. (3) for brittle materials, which should not be subjected to tensile stress, occurs when

$$\gamma\sec\theta = 1$$

Assuming $\gamma = 0.2$, which will be found to be in good agreement with Eq. (4), the limiting value of β becomes about 0.5, and for the cast iron mentioned in paragraph (H) the limiting value of l/r appears to be about 95, in contrast to the value of 70 usually prescribed.

(J) Assuming $s_c = 3s_w$, the Forest Products laboratory formula for wood:

$$\frac{P}{A} = s_w\left[1 - \frac{1}{3}\left(\frac{l}{b}\right)^4\frac{16}{\pi^2}\frac{36{s_w}^2}{E^2}\right]$$

reduces to

$$\alpha + (64/27)\,\beta^4 = 1 \qquad (5)$$

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and, when plotted, the resulting curve lies somewhat above the Johnson parabola (Eq. (2)).

(K) Of the equations so far given, Eq. (3) is the most general since it includes the major variable eccentricity. Eq. (3) can be plotted as a family of curves, using γ as a parameter. The values of α and β, computed for ten postulated values of γ, are given in Table 1.

(L) If Eqs. (1), (2), (4), and (5) are plotted on the same sheet with the family of curves mentioned in paragraph (K), it will be found that the curve representing Eq. (3) for $\gamma = 0.1$ will serve as a good average, while the curve representing Eq. (3) for $\gamma = 0.2$ will represent the most conservative case.

(M) From paragraph (L), one may infer that effective eccentricity of loading, accidentally encountered from all sources (including lack of straightness), assumes an average value of $0.1\ r^2/c$ and a maximum value of $0.2\ r^2/c$. Since both r and c are directly proportional to the linear dimension of the cross-section, this means that effective eccentricity, sometimes considered to be out of control, tends practically to amount to a predetermined statistical value, dependent on the linear dimension of the cross-section, and *not* dependent on the *length* of the column unless the discussion be restricted to geometrically similar columns (columns of identical slenderness ratio). Evidently, for columns intended to be axially loaded, this accidental effective eccentricity can be taken care of by assuming $\gamma = 0.1$ for good average conditions and $\gamma = 0.2$ for those conditions which are slightly poorer than average. The column designer can apply his judgment (through choice of γ) as to whether the eccentricity control is average or poorer than average.

(N) To check the validity of the assumption of $\gamma = 0.1$ for average laboratory loadings, Eq. (3) for $\gamma = 0.1$ can be used (through Table 1) to predict a P/A versus l/r curve for Fig. 12, reference 3, on which are shown test data for seven 17*S*-*T* specimens of unlike shapes. When plotted, this curve will be found to agree perfectly with the average test results for values of l/r greater than 30. At low values of l/r or β a column can continue to carry load for a short time after some of the column material has reached yield stress, just as a beam can offer a resisting moment in excess of that calculated on the basis of yield stress at the most extreme filament. This explains the lack of agreement for values of l/r less than 30.

(O) It is felt that the lack of agreement mentioned in paragraph (N) is of no concern to the column designer, who, like the beam designer, is generally interested in the load which will set up yield stress, rather than the load that will produce complete failure. This point of view was expressed by D. H. Young[4] in 1934.

(P) In the "design case," the column problem knowns are $P, l, \gamma, E, s;$ while the unknowns are A and r. Even with the aid of the dimensionless chart based on Table 1, such a problem yields only to the process of trial and error.

Consider, however, another dimensionless quantity, the value of which normally ranges between zero and unity, defined as follows:

TABLE 1

Values of α and β in Eq. (3)

$\downarrow\gamma$	$\theta\rightarrow$	0°	30°	45°	60°	90°	90°	90°	90°	90°	90°	
0	α	1.00	1.00	1.00	1.00	1.00	.695	.510	.390	.308	.250	
	β	0	.167	.250	.333	.500	.600	.700	.800	.900	1.00	
	$\theta\rightarrow$	0°	30°	45°	60°	80°	82.5°	86°	87°	88°	89°	89.5°
0.001	α	0.999	0.999	0.999	0.998	0.998	0.992	0.985	0.982	0.972	0.946	0.896
	β	0	0.167	0.250	0.333	0.416	0.460	0.481	0.487	0.497	0.509	0.525
0.01	α	0.990	0.986	0.984	0.980	0.963	0.930	0.873	0.838	0.777	0.637	0.465
	β	0	0.168	0.252	0.336	0.424	0.476	0.511	0.528	0.555	0.621	0.730
0.05	α	0.950	0.945	0.930	0.909	0.838	0.722	0.583	0.510	0.411	0.148	
	β	0	0.172	0.260	0.350	0.456	0.540	0.625	0.678	0.765	1.29	
0.1	α	0.910	0.895	0.875	0.833	0.725	0.565	0.411	0.344	0.259		
	β	0	0.177	0.267	0.364	0.489	0.610	0.744	0.825	0.964		
0.2	α	0.833	0.811	0.778	0.713	0.565	0.394	0.258				
	β	0	0.186	0.284	0.393	0.553	0.730	0.940				
0.4	α	0.713	0.683	0.638	0.555	0.394	0.246					
	β	0	0.202	0.313	0.446	0.662	0.923					
0.6	α	0.625	0.590	0.541	0.454	0.302	0.178					
	β	0	0.217	0.340	0.494	0.755	1.09					
0.8	α	0.555	0.520	0.470	0.384	0.246	0.374					
	β	0	0.232	0.364	0.537	0.838	1.23					
1.0	α	0.500	0.463	0.415	0.333	0.206						
	β	0	0.245	0.388	0.575	0.915						
2.0	α	0.333	0.302	0.261	0.200	0.115						
	β	0	0.304	0.490	0.745	1.23						

$$\lambda = \frac{\pi^2}{5}\left(\frac{E}{s^2}\right)\left(\frac{P}{l^2}\right)\left(\frac{r^2}{A}\right)$$

Based on the "K factor" idea developed in 1937 by W. H. Clapp[5], this quantity λ might be called a shape coefficient, the value of which is constant for *geometrically similar* cross-sections, constant load, constant length, and given material. It is related to the primary coefficients, α and β, as follows:

$$\alpha = 20\lambda\beta^2 \qquad (6)$$

On the α *vs.* β chart, Eq. (6) plots as a family of parabolas intersecting the γ curves at nearly right angles.

In the common case, then, requiring selection to be made from geometrically similar shapes, the procedure is:

(1) From material, length, load, and assumed shape, compute λ.

(2) From chart based on Table 1, to which the λ curves have been added, find the value of α corresponding to the intersection of the pertinent λ and γ curves.

(3) From the value of α just found, compute A.

In this manner the process of trial and error is eliminated.

The final conclusion is that all ordinary column problems, regardless of material, slenderness ratio, or amount of effective equalized eccentricity, can be solved using one chart based on Eq. (3) and plotted from Table 1.

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Book Reviews

Flight without Power, by LEWIN B. BARRINGER; Pitman Publishing Corporation, New York, 1940; 251 pages, $3.50.

Mr. Barringer, N. H. Randers-Pehrson, Milton Stoughton, Paul and Ernest Schweizer, Karl O. Lange, and Charles H. Colvin, have collaborated to make this book an authoritative account of the various aspects of flight without power. No mathematics beyond simple algebra is used. A high-school course in physics is sufficient prerequisite for an understanding of the subject matter.

In the chapter on aerodynamics the formulas for the lift and drag coefficients have a factor, K, which according to the author depends on the units used. It would seem preferable to give K as $^1/_2$ and specify that consistent units must be used. The printing of the mathematics leaves something to be desired; symbols are not italicized and in most cases subscripts are not depressed. These points do not, however, seriously detract from the value of the book.

Chapter headings are: "History of Motorless Flight," "Aerodynamics," "Types of Gliders," "Design, Construction and Maintenance," "Launching Methods," "Soaring Meteorology," "Instruments," "Flight Training," "Soaring Technique," "Soaring Sites," "Clubs," and "Future of Gliding and Soaring." An appendix gives statistical data and biographical sketches of the first ten American "Silver C" pilots.

People who are interested in taking up gliding and those who are considering the formation of clubs will find this book very much worth while. It is safe to say that many experienced pilots will find in it information which they can profitably absorb.

Diesel Monitor, by JULIUS ROSBLOOM; Diesel Engineering Institute, Newark, New Jersey, 1940; 524 pages, $5.00.

The object of this book is to simplify the solving of problems encountered in Diesel service. It is almost entirely in the form of questions and answers. The subject matter is simplified to the extreme. Aviation Diesels are barely mentioned.

A large number of diagrams illustrate the working parts and many photographs of actual installations are included.

The book is divided into ten sections, treating definitions of terms and elementary thermodynamics, types of Diesels and their utilization, compressors and accessories, pumps, physical properties and purification of oils, valves, trouble shooting, tanks and piping systems, and piston rings and the use of indicator cards. The last 200 pages of the book are taken up with license examination questions for various grades of Diesel engineers, and miscellaneous information on aviation, maneuvering practice for marine service, etc.

The Weather Eye, by C. R. BENSTEAD; Robert Hale, Ltd., London, 1940; 287 pages, 8s., 6d.

"An Irreverent Discourse upon Meteorological Lore, Ancient and Modern, with Many Indiscreet References to the Art of Forecasting as Now Practiced" is the subtitle of this entertaining book. It takes the meteorologist to task for his inaccuracies and the vagueness of his forecasts; it takes the layman to task for depending upon the moon and other discredited signs of the weather to come.

The author, a meteorologist with the British Navy, combines entertainment with instruction. Frontal analysis and movement are described while deploring the fact that they do not always behave according to the predictions based upon the available observations.

In spite of the fact that the book aims primarily toward teaching the Englishman something about his particular brand of weather it will nevertheless be of interest to American readers.

Aero Engines and Their Laboratory Testing Under Flight Conditions*

LOUIS MASSUGER

Société d'Exploitation des Matériels Hispano-Suiza, France

SUMMARY

THE author begins by discussing recent drag and cooling improvements of both air-cooled and liquid-cooled aircraft engines and mentions the latest cooling versions as being the baffled air-cooled engine enclosed in an N.A.C.A. cowl and the high-coolant-temperature liquid-cooled engine with encased or buried radiators.

The latest Hispano engine, which is an "H" type, liquid-cooled model is described. It drives two oppositely-rotating coaxial propellers, each of which is geared to half of the total number of cylinders as a complete operating unit which may be stopped at any time without impairing the operation of the other half of the unit.

Vibration Dampers

It is known that the maximum fatigue resulting from explosion pressures on the crankshaft may be multiplied when one of the harmonics of the motor torque coincides with the natural period of torsional oscillation of the crankshaft. Furthermore, the connecting rod systems of air-cooled engines, with auxiliary rods pivoted to a master connecting rod is a further cause of vibration. It produces a relatively important harmonic torque of the first order, *i.e.*, low frequency, and an inertia force rotating at twice the speed of the crankshaft, in the same direction.

The Sarazin type of vibration damper consists of oscillating movable masses mounted similar to freely suspended pendulums on the crankshaft, in the field of the centrifugal force. Their mass, center of gravity and low radius of oscillation makes it possible to compensate at normal engine speeds for torques of the order of the natural period of the crankshaft. These, in conjunction with two circumferentially movable pendulums in the fixed counterweight of the crankshaft, provides an efficient means of vibration damping.

The Hispano-Suiza Corporation is also installing vibration dampers on its new liquid-cooled V type engines of 1200 hp., for eliminating the harmonic of order $2^1/_2$ of the gas pressure torque. This damper consists of two pendular masses arranged at 180°. The crankshaft of this engine is identical with that of an ordinary 860 hp. engine, except for the addition of the vibration dampers; the total weight of these is about 3 kg.

Compressors

Nearly all of the compressors used at the present time on aviation engines are of the centrifugal type and are mechanically driven. Their turbines are of forged light metals, such as duralumin or magnesium alloys, which, despite their low mechanical strength, give good results because the fatigue due to centrifugal stresses decreases with the density.

The mechanical drive, in addition to the speed multiplying gears, generally includes an elastic drive and a torque limiting device. The latter, intended to limit the stresses due to speed variations, has been dispensed with by some manufacturers.

Considerations of flexibility in application have led to the development of the two-speed compressor. In this case, the high speed is adapted to flight at the maximum altitudes, and the low speed permits efficient supercharging at ground level and at intermediate altitudes. The speed changing device is often of the hydraulic type and can be made automatic.

Turbo-Compressors

The mechanical drive of the compressor seems to constitute only a temporary solution. Turbo-compressors are industrially used in connection with Diesel engines but, for aviation engines, the following difficulties are encountered: (1) at the present state of the art the carburetors available do not permit scavenging; (2) the temperature of the exhaust gases is 800–850°C., as compared with temperatures of 500°C. in the case of the Diesel engine; (3) questions of weight and space occupied play an important part.

It is likely that, in the course of time, carburetors will be replaced by gasoline injectors and scavenging will be easily applicable. With regard to weight, every effort has been made to reduce it as much as possible and apparatus produced in the United States and abroad have been adapted to aviation engines.

* Pressure for space in the Journal prevents publication of M. Massuger's complete article on this subject. The paper was prepared by the author for presentation at the International Congress of the Aeronautical Sciences, scheduled to be held on September 11 to 16, 1939, in New York. Because of the international situation the Congress was postponed until 1941. A summary of the paper was presented at the Power Plants Session, Eighth Annual Meeting, I.Ae.S., New York, January 24, 1940.

Gasoline Injection

Gasoline injection, already applied in quantity production for certain makes of engines, has the following advantages: (1) equal distribution, the injection being effected separately in each of the cylinders; (2) optimum composition of the mixture for all working conditions; (3) elimination of the possibility of ice formation; (4) elimination of back-fire; (5) works correctly in all flying positions; and (6) a wider range of fuels can be used.

The optimum composition of the mixture and its perfect distribution, in addition to the elimination of re-heating, improve the operation of the engine and its power, while substantially reducing the fuel consumption.

However, the adaptation of the system already in use on oil engines is difficult. In order to operate at the high pressures necessary, the measuring pumps of the piston type and the hydraulically controlled injectors must be manufactured with great precision. They cannot be lubricated with gasoline, benzol or alcohol, and at high rotational speeds the mechanism is delicate.

Another system can be employed in which the injector is placed ahead of the intake-valve, in the cylinder air-duct. The injection-pressure required is then comparatively low, and a rotary pump ensures adequate feeding.

A mechanical, hydraulic or electrical device controls the injectors at opening and closing.

This solution does not seem as good as that used for oil-engines, since the injector position and pulverization are less perfect, but presents certain advantages through its simplicity.

Reduction Gears

The use of reduction gears in limiting the tip speeds of propellers is illustrated by the following example:

Two identical fighting planes with engines of the same type and rated power were flight tested. One had a propeller absorbing 860 hp. at 2260 r.p.m., the other 860 hp. at 1600 r.p.m.; in the latter case a reduction gear was installed. The tip speed of the former was $1.03c$ and of the latter $0.94c$, where c is the speed of sound under the conditions of the test. The top speeds of these planes were 440 and 490 km. per hour, respectively, indicating a gain of 9 per cent due to the reduction gearing.

Co-Axial Propellers

The two main advantages of co-axial oppositely rotating propellers are elimination of (1) the engine torque, and (2) the swirl of the slipstream.

Wind tunnel tests and practical experience have shown that the total efficiency of two co-axial, oppositely rotating, two-bladed propellers is, for high pitch propellers, at least equal to if not greater than that of a single two-bladed propeller. At any rate, it is always 2 to 5 per cent greater than that of a four-bladed propeller with the same power input. The coincidence of the propeller blades twice during each revolution apparently does not introduce excessive vibration, provided the distance between the planes of rotation is greater than one-tenth of the diameter of the propellers.

Testing Aircraft Engines Under Flight Conditions

The author discusses the Hispano-Suiza altitude chamber and the Hispano-Suiza engine test wind tunnel. The altitude chamber is capable of testing a 1200 hp. engine to an altitude of 10,000 meters, and consists mainly of a test dynamometer, a refrigerating plant for cooling the intake charge, an exhaust gas extractor and a cooling blower. The refrigerating plant is driven by a 300 kw. electric motor and permits temperatures down to $-55°$ C. in the test chamber. The exhaust gases, after being cooled and freed from corrosive elements in a water drip washer are discharged into the surrounding atmosphere by means of a compressor acting as an exhauster. The suction compressor is of the two stage type. One stage is used to simulate altitudes up to 5000 meters; for altitudes between 5000 and 10,000 meters both stages are required.

The wind tunnel (see Fig. 1) is stated to be "the most important private plant of this kind existing in the world." The maximum attainable air velocity at the

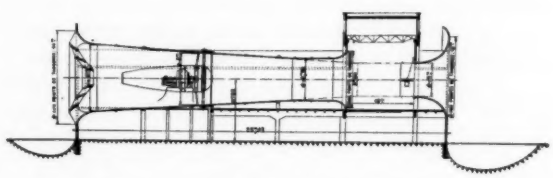

FIG. 1. Cross-section of the big Hispano-Suiza wind tunnel (Bois-Colombes).

throat of the tunnel is approximately 210 m.p.h. This tunnel is capable of measuring the lift, drag and rolling moment of a nacelle or fuselage unit and the structure is capable of mounting and testing an engine of a maximum output of 2000 hp. The apparatus is so constructed that the angle of attack of the engine and nacelle can be varied from normal climbing attitude through the horizontal position to normal diving attitude. It allows not only the engine, but also the propeller, engine cowling and radiator installations to be tested under numerous flight conditions at sea level density. The tunnel is now being fitted with a smoke apparatus to enable studies of aerodynamic shapes. The author expects that new improvements in the technique of constructing and installing aircraft engines will result from the use of these new pieces of test apparatus.

Shell Aviation Scholarships and Awards

THE Shell Aviation Scholarships and Awards established by the Institute under a grant from the Shell Oil Company, were completed in Washington, D. C., on August 17th. The final contest, at which the winners of the seven regional contests competed, was held at Bolling Field. The contestants were judged by a board consisting of Major Lester D. Gardner, Executive Vice-President of the Institute; Lieut. Comdr. J. W. Geppert, U.S.N.; Capt. J. W. McCoy, U.S.A.; Lieut. Charles Parker, U.S.M.C.; and Prof. Frederick K. Teichman, New York University.

Edward F. Scanlon of Kenyon College, Gambier, Ohio, won the first award, consisting of a $1000 scholarship. Jefferson Davis Lewis of the University of Florida won the second place scholarship of $750, and Waldo E. Schroeter of the University of California received the third place scholarship of $500. Other contestants, winners of regional contests, were: Barbara Jane Erickson of the University of Washington, Arden E. Hixson of Chadron State Normal School (Nebraska), John L. Lambert of the University of Maryland, and James G. White of Daniel Baker College, Texas.

After the contest the fliers proceeded to the office of Hon. Robert H. Hinckley, Assistant Secretary of Commerce. After expressing his appreciation to the Institute for sponsoring the contest and to the Shell Oil Company for contributing the funds, Mr. Hinckley announced the winners and made the awards.

On Friday, August 16th, a luncheon was held, attended by more than 200 guests, many of them prominent government and aviation officials. Unfavorable weather prevented the final contest from being held prior to the luncheon, as was originally planned.

Speakers at the luncheon were: Major General H. H. Arnold, Chief of the Army Air Corps; Capt. Geo. D. Murray, U.S.N., Chief of the Personnel Division, Bureau of Aeronautics, Navy Department; Hon. Robert H. Hinckley, Assistant Secretary of Commerce; Dr. George W. Lewis, Director of Research, N.A.C.A.; Major James H. Doolittle, President of the Institute; and Major Lester D. Gardner, Executive Vice-President of the Institute.

Major Doolittle awarded to each contestant an aviation wrist watch and presented to Dean J. R. Jenison of Tarkio College (Missouri) the Shell Intercollegiate Aviation Trophy for establishing the most proficient record for training pilots in the C.A.A. program. Dean Jenison also received, for Mr. Earle Coe, who trained the students at Tarkio College, the Shell Flight Training Trophy.

The speakers at the luncheon stressed the contribution which the contest has made to the flight training program of the C.A.A. The Shell Company set aside $15,000 to be used by the Institute in establishing and administering the scholarships and awards. The Institute prepared the rules and regulations and appointed a National Board of Awards and committees of Regional Judges.

The National Board of Awards consisted of Dr. Guy E. Snavely, Director, Association of American Colleges; Col. Edgar S. Gorrell, President, Air Transport Association of America; Col. John H. Jouett, President, Aeronautical Chamber of Commerce of America; Mr. Gill Robb Wilson, President, National Aeronautic Association; Mr. Douglas O. Langstaff, President, National Association of State Aviation Officials; and Major Lester D. Gardner.

More than 500 universities, colleges and sponsor organizations, participating in the C.A.A. Pilot Training Program, competed for the awards. Seven regional contests were held early in August. The seven winners competed in the final contest in Washington.

Book Review

Practical Radio Range Data, Range Data, Inc., P. O. Box 1752, Dallas, Texas; subscription prices: U. S., $27.00; U. S. and Canada, $28.50; assorted sheets, $0.20 each.

This is a loose-leaf manual containing the essential items of information concerning the radio aids available to pilots of radio equipped aircraft. In addition it includes valuable information pertaining to the airports served by the ranges and the obstructions and terrain features surrounding them.

Radio range data sheets are included for each of the 294 radio range stations and localizers in the United States and 41 in Canada. Manuals are available for any selection of ranges desired. A complete list of radio facilities, indicating the watch frequencies guarded, arranged alphabetically according to identification signals, is included.

The individual sheets are $3\frac{1}{2} \times 6$ inches, including a very readable map with the above information arranged in a convenient form and a tabular list of data giving call letters, range and voice frequencies, distance and direction of the range stations with respect to the field, etc.

The subscription prices given above include semi-monthly revision service for one year. This service includes sheets for ranges newly commissioned, to be inserted in the loose-leaf folder, and new sheets, as required, for each revision or alteration which may occur for the sheets included in the manual. Additional service, after the first year, is available at a reduced price.

This manual will undoubtedly be a great aid to private pilots, particularly inasmuch as the information is kept constantly up to date.

Institute Notes

Rules and Requirements of The Paul Kollsman Library

Two New Publications to be Issued

The Paul Kollsman Library is now ready to loan aeronautical books to its members. All members of the Institute have received application blanks for membership in the library. The requirements and rules are printed below.

Membership in the Library is open to all members of the Institute of the Aeronautical Sciences and to any person in the United States over 18 years of age who can furnish references which certify as to his responsibility and reliability.

There will be no charge made for the service but borrowers will be required to adhere to the rules of the Library so that it may be of the greatest benefit to members.

An application must be filled by all persons desiring to become members of The Paul Kollsman Library. NON-MEMBERS of the Institute are required to submit the names of two persons who will vouch for their reliability and responsibility. The references should preferably be professional men, bankers, or business men. Non-members of the Institute may also become members of the library, without submitting the above references, by depositing ten dollars which will be returned to them in full upon their resigning from membership in the Library.

Membership Rules

1. Books must be ordered on forms provided by the library. Only one book may be on loan to a member at any one time. Under present conditions books will not be mailed outside the United States.
2. A borrowed book must not be kept more than SEVEN DAYS unless members wish to purchase it. Violation of this rule will cause immediate suspension of membership.
3. Members who wish to purchase books should send a check or money order to The Paul Kollsman Library within seven days after receipt of the book. The list price is shown on the cover.
4. Books must be returned in the same wrappers in which received using the self-addressed return label furnished. Return postage must be paid by the borrower.
5. Books must be carefully handled, and pages must not be marked, mutilated or soiled.
6. Certain rare books and books valued at over $10.00 may be borrowed if the member makes a deposit of the value of the book and prepays the postage and mail insurance.
7. Magazines and house organs are not available for loan, but members may order photostatic copies at usual rates.

Publications

Two new publications will be issued by the Institute in September. Members of the Institute will receive these in return for their membership dues.

The list of books available for loan will be found in *The Aeronautical Reader's Guide* which will be published quarterly by The Paul Kollsman Library. Only a few books published before 1930 are indexed, as a complete list of books on aeronautics is available elsewhere. New titles will be listed in each issue of the Guide.

The Aeronautical Review, to appear monthly, will contain reviews of books, magazine articles, house organs, and catalogues. It will enable members to keep up-to-date on the rapidly expanding aeronautical literature.

Gifts to the Institute

The Institute gratefully acknowledges receipt of the following gifts.

The library of the Bendix Aviation Corporation sent a large number of old aeronautical magazines. Miss Dorothy Monro of Newton Lower Falls, Massachusetts, added a collection of newspaper clippings to the biographical and subject files of the Archives. The Jadur Import Company presented a "Flight Calculator." E. W. Roberts sent one of his power calculators. The Rohm and Haas Company of Philadelphia mounted several of the medallions in the Archives collection in Plexiglas. Harold McCormick presented a copy of *Aeronautical Prints and Drawings* by Col. W. Lockwood Marsh. Robert G. Fowler sent a piece of radiator tubing from Herbert Latham's monoplane "Antoinette," in which he made the first attempt to cross the English Channel from France to England. A collection of clippings about women in aviation was received from Miss Clara Studer.

Personnel Opportunities

The Personnel Bureau serves individual members, as well as organizations seeking to employ aeronautical specialists. Any member or organization may have requirements listed without charge.

Wanted

Chief Designer for work with aircraft company. Must have the following qualifications: Five years' experience in aircraft design, including aerodynamic calculation and stress analysis; knowledge of modern aircraft construction and analysis methods; must have been associated with successful aircraft designs within recent years; college degree in engineering (any branch); customary human relation standards. It is also preferable that he have a knowledge of hull design and hydrodynamic calculations on seaplanes and experience as a draftsman. Salary expected should be specified. Address reply to Box 105, Institute of the Aeronautical Sciences.

The Aeronautical Engineering Department of a large midwestern University has openings for two instructorships at approximately $2000 each, one teaching assistantship at $600, one research fellowship at $300. Appointments are for 9 months starting September 15th. Applicants for instructorships must have a minimum of one year of practical experience in the aeronautical field and hold a bachelor's degree in Aeronautical Engineering; preference will be given to candidates holding master's degrees. Teaching assistant and research fellow should hold bachelor's degrees in Aeronautical Engineering. All of the above positions carry remission of tuition fees in the Graduate School and present opportunities for graduate study toward advanced degrees. Ample laboratory facilities are available for research in all fields of aeronautical engineering. Special courses and equipment are available for investigation of problems relating to high altitude flight. Address reply to Box 106, Institute of the Aeronautical Sciences.

Available

Aeronautical Engineer with 30 years' experience in the design, construction and flying of military and commercial airplanes desires connection with reliable concern that is equipped to fabricate parts and sub-assemblies for airplanes with ultimate

goal of manufacturing complete airplanes for the Services under the present Army and Navy expansion program. Address reply to Box 107, Institute of the Aeronautical Sciences.

Experienced preliminary layout engineer desires connection with reliable organization on the west coast. Address reply to Box 108, Institute of the Aeronautical Sciences.

Student Branches

Casey Jones School of Aeronautics. At the last meeting of the Student Branch the following officers were elected: Milton F. Edwards, Chairman; Daniel Howland, Vice-Chairman; Donald F. Brodie, Secretary; Norman Mayer, Treasurer; Joseph Donahue, Sergeant at Arms. At other recent meetings the films "Trans-Pacific Flight," and "Streamline Visualization" by C. Witoszynski were shown. The former was shown through the courtesy of Pan-American Airways.

Changes in Membership

The following changes in the membership of the Institute have occurred since the publication of the previous issue of the Journal.

Elected to MEMBER Grade

Belinn, Clarence Mauritz, M.I.Ae.S.; Vice-Pres. & Gen. Mgr., Kansas City Southern Airlines.

Bleakney, William McChesney, Ph.D.; M.I.Ae.S.; Research Engineer, Lockheed Aircraft Corp. (See A.M. of S.)

Brymer, John Hanway Parr, M.I.Ae.S.; Technical Assistant, Air Ministry. England.

Cheney, Harold Knox, Ae.E.; M.I.Ae.S.; Asst. Chief of Aerodynamics—Flight Test, Vultee Aircraft Div., Aviation Mfg. Corp.

Cornelius, George Wilbur, M.I.AeS.; Pres. & Chief Engineer, Cornelius-Hoepli Corp.

Ellis, Chester Arthur, B.S. in M.E.; M.I.Ae.S.; Asst. Project Engineer, Wright Aeronautical Corp.

Martin, Wilbur Allison, M.E.; M.I.Ae.S.; Aero. Structural Engineer, Brewster Aeronautical Corp.

McKiernan, William John, M.I.Ae.S.; Major, U.S. Army Air Corps.

Naumann, Donald Jerome, B.Ae.E.; M.I.Ae.S.

Orville, Howard Thomas, S.M.; M.I.Ae.S.; Lt. Comdr., U.S.N.; Engineer Officer (Aerology), U.S. Navy.

Pavlecka, Vladimir H., B.S. in E.E.; Chief Research Engineer, Northrop Aircraft, Inc.

Shelton, Thomas Miles, B.S.; M.I.Ae.S.; Technical Director, Aero Industries Technical Inst.

Southack, Tilden Ward, B.S.; M.I.Ae.S.; Vice-Pres., The Acrotorque Co.

Stewart, William Fred, B.S. in Ae.E.; M.I.Ae.S.; Chief of Structures, Spartan Aircraft Co.

Sullivan, Eugene Dennis, B.S.; M.I.Ae.S.; Asst. Chief Engineer, The Acrotorque Co.

Upton, Virgil S., B.Sc.; M.I.Ae.S.; Stress Analyst, Vega Airplane Co.

Ward, Kenneth Edwards, B.S. in M.E.; M.I.Ae.S.; Experimental Engineer, Consolidated Aircraft Corp.

Weining, Earl Oliver, M.I.Ae.S.; Chief Engineer, Spartan Aircraft Co.

Elected to Industrial Member Grade

Emil, Allan D., LL.B.; M.I.Ae.S.; Attorney-at-Law; Member, Board of Directors, Square D Company.

Glowinski, Albert David, B.S.; M.I.Ae.S.; Engineer, Soc. des Moteurs Gnome Rhone. France.

Gott, Edgar Nathaniel, B.S.; M.I.Ae.S.; Vice-Pres., Consolidated Aircraft Corp. (See W.W. in A.)

Mohler, Orville, E., B.S.; M.I.Ae.S.; Asst. to the Pres., Menasco Mfg. Co.

Elected to Technical Member Grade

Boden, Robert Hector, Ph.D.; Research Engineer, Lockheed Aircraft Corp.

Brooks, Emerson Hayden, B.S.; Engineer, Lockheed Aircraft Corp.

Buschmann, Rudi Paul, Ae.E.; Junior Stress Analyst, Lockheed Aircraft Corp.

Christy, Roland, Draftsman, Vought-Sikorsky Aircraft, United Aircraft Corp.

Conviser, Albert A., B.S. in Ae.E.; Sales & Advertising Manager, Uneeda-National, Inc.

Dutton, Donnell Wayne, M.S. in Ae.E.; Stress Analyst, St. Louis Airplane Div., Curtiss-Wright Corp.

Gitt, Edward, Ae.E.; Engineer, Republic Aviation Corp.

Horton, Claude Leslie, Secretary, Board of Directors, Indiana Air Service, Inc.

Humphrey, William Vincent, Assistant Associate Editor, Journal of the Aeronautical Sciences.

Kreisler, Sol S., B.S. in M.E.; Aerodynamicist, El Segundo Div., Douglas Aircraft Co.

Lane, Winford Josiah, B.S. in M.E.; Group Engineer, Lockheed Aircraft Corp.

Moore, Morton Estes, M.S. in E.E.; Engineer, Douglas Aircraft Co.

Prusas, Victor Joseph, B.S.; Stress Analyst, North American Aviation, Inc.

Silliman, John Calvin, C.E.; Asst. Engineer, Structures Dept., Pacific Railway Equipment Co.

Smith, Roy, B.Ae.E.; Senior Stress Analyst, Lockheed Aircraft Corp.

Thayer, Harold Brooks, Sales Representative, Boeing School of Aeronautics.

Thompson, Douglas Graham, M.E.; Mechanical Research, Lockheed Aircraft Corp.

Veck, Milton F., B.S.; Engineering Draftsman, St. Louis Airplane Div., Curtiss-Wright Corp.

Vogel, William Franklin, C.E.; Junior Stress Analyst, Glenn L. Martin Co.

Wendt, Harold Otto, M.Ae.E.; Aerodynamicist, Curtiss Aeroplane Div., Curtiss-Wright Corp.

Transferred to Associate Fellow Grade

Maurice A. Biot, Asst. Prof. Mechanics, Columbia University; Oscar Erlandsen, Jr., Engineer, Grumman Aircraft Engineering Corp.; John Harding, Jr., Sales Engineer, Pump Engineering Service Corp; William Curtis Rockefeller, Chief of Aerodynamics, Vultee Aircraft Div., Aviation Mfg. Corp.

Transferred to MEMBER Grade

Charles James Gallant, Jr., Research Engineer, North American Aviation, Inc.; Ernest Joseph Adolph Greenwood, Jr., Engineer, Vought-Sikorsky Aircraft, United Aircraft Corp.; Fred S. Kramer, Independent Aero. Consultant; Fred Carl Meltzer, Associate Editor, The Aeronautical Review.

Transferred to Technical Member Grade

Arnold H. Egly, Meteorologist, American Airlines; Jack E. Frick, Engineer, Vega Airplane Co.; James D. Heighton, Engineer, Timm Aircraft Corp.; David Angen Hsiung, Student Engineer, Chinese Aeronautical Committee; Mitsugi Nishikawa, Asst. Engineer, Nakajima Aircraft Co., Japan; Samuel B. Sherwin, Aerodynamicist, Grumman Aircraft Engineering Corp.; Jaime Alberto Vendrell, Apprentice Engineer, Pan American-Grace Airways, Peru.

Aeronautical Reviews

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps

Aircraft Design

Study of the Adaptation and Performance of the Entire Airplane-Engine-Propeller Group by the Method of Curves of Utilization. R. Silber. Study of the performance in horizontal flight of an airplane equipped with a variable-pitch propeller. Curves are given and formulas are derived for the following: relation between the performance parameters of airplane and propeller; values of rotating speed and torque; study of the curve of utilization at constant n and $n = n_0$ at the altitude of adaptation; study of the curve of utilization at constant torque $C = C_m$; curve completely replacing the polar of the airplane itself; curves of utilization for constant n at the same altitude; curves of utilization for constant n at all altitudes; values of the speed, rotating speed, and engine torque at each point of operation; study of the variation of utilizable zones with altitude; study of the operation of the engine; and determination of the performances. Continued from the fourth issue 1938 and first issue 1939. *La Technique Aéronautique*, 4th quarter, 1939, pages 142–159, 14 illus., many equations.

Burnelli Announces a Marine Engine. Burnelli has considered putting an auxiliary marine engine in his airplanes which could be used in case of a forced landing on the water. This engine would be located in the rear of the central portion of the wing-fuselage, in the compartment arranged for the baggage. The shaft carrying the marine propeller, retractable during flight, could be immersed in case of necessity, by means of a remote control. Brief reference only. *Les Ailes*, May 23, 1940, page 4, 1 illus.

The Estimation of Level Speed. K. Turner. Simple routine method for estimating the level speed of an airplane under any conditions is presented as an alternative to the method described by C. F. Toms in the October 5, 1939 issue. Present method is a direct one enabling an accurate answer to be obtained straight off without successive approximations. Accuracy is limited only by the accuracy with which the graph can be read. *Flight, Aircraft Engr. Sup.*, June 27, 1940, pages 25–26, 1 illus., 3 equations.

Lift Distribution. J. A. C. Williams. Possible effect of high-speed flight on wing stressing. Considerable readjustment of thrust distribution can occur on the propeller blade when rotating so that tip sections travel at or above the speed of sound. Causes for this readjustment are pointed out. The effect of v/a (the ratio of velocity of flight to the local speed of sound) on the slope of the lift curve of a wing is shown in a graph for three N.A.C.A. airfoils, three Joukowski-type R.A.F. airfoils, and one Italian-section airfoil, with indication that lift falls off sooner for the thicker sections. Since most wings are thinner at the tip than at the root, as v/a increases so the loads must be thrown toward the tip of the wing. Bending and shear loads will be increased along the wing, and moment coefficient of the section increases and so modifies the torque.

A factor is plotted by which the speed of sound at any altitude can be found. If the diving-speed restriction is only applied to aircraft in the form of I.A.S., and the effects of v/a given actually occur in free flight, heavy loads will be thrown on the wing tips at altitudes higher than 5000 ft. Table shows speed of sound at various heights with the corresponding I.A.S. for an aircraft flying at $v/a = 0.7$. Angle of attack of the airfoil has an effect on the shock-stalling speed. Lift distribution can be calculated by the Lotz method, the various values of $\delta C_L/\delta\alpha$ along the span being substituted. *Flight, Aircraft Engr. Sup.*, June 27, 1940, pages 26–27, 3 illus., 1 table.

A Simple Approximate Method for the Determination of Lift Distribution along the Wing Span. O. Schrenk. Approximate method described permits the calculation of lift distributions in a few minutes. Comparison with an exact method shows an agreement satisfactory for many purposes. The possibilities of application are further reaching than in the case of the exact method of calculation, and also include the case of the wing with plates at the tip. *Luftwissen*, April, 1940, pages 118–120, 13 illus., equations.

Rotary-Wing Aircraft

Return to an Old Love. H. W. Perry. "Sikorsky designs and demonstrates a successful helicopter." Short account is given of the demonstration flight of the helicopter which fully proved the ability of the helicopter to move in any direction and to turn in flight under full control. Design of the helicopter is described. *Flight*, June 27, 1940, pages 569–570, 1 illus.

Rotary-Wing Aircraft. J. A. J. Bennett. Rotational oscillation is considered in detail including: measurement of the hinge motion in flight; frictionless damping; bending at the blade root during flight; and the relationship between horizontal bending produced at the blade root by the drag hinge restraint and stability of rotational oscillations.

Frictional damping and its associated maintenance troubles can be avoided by tilting the axis of the drag hinge through an angle α_2 in a plane perpendicular to the radial axis of the blade so that displacements about the drag hinge have both flapping and rotational components but have only a negligible feathering component. Two photographs show a cine-camera mounted at the blade root for recording rotational displacement about the drag hinge, one photograph applying to a hinge having α_2 restraint but no friction damper, and the other to a hinge having frictional damping. Four graphs give typical drag-hinge oscillations in flight at 70 m.p.h., two for frictional damping of 8- and 12-lb. static pull at the blade tip, respectively, and the other two without friction dampers but with $\alpha_2 = 60°$ and 65°, respectively. Continued. *Aircraft Engg.*, June, 1940, pages 174–176, 8 illus.

Tests on Helicopters Carried Out in Belgium. N. Florine. Wind-tunnel tests on three types of helicopters, theoretical considerations, evaluation of wind-tunnel test results, tests of two types of helicopters in full-scale construction, and conclusions reached from results of the full-scale tests are described. Illustrations include: test arrangement in the wind tunnel equipped with a device for periodic variation of the angle of attack of the rotor blades; test arrangement in a wind tunnel of a model with hinged rotor blades suspended from the balance at a positive angle of attack; curves for the dependence of C_T, C_w, C_Q, and C_a of V/nD; polar curves of the rotor in the cases of $V/nD = 0$, 0.4, 0.8, and 1.2, respectively; curve of the infinite extension of the uncalculated polar of the blades of the model rotor in the wind tunnel at 30 meters/sec.; test values of the determined polar and induced polars of the model rotor for various values of V/nD; efficiency coefficients for the model and full-scale rotors; curves for the distribution of total power to power on the shaft and propeller output; and various photographs of the two types of helicopters tested in full scale, and parts of the hub. *Luftwissen*, April, 1940, pages 104–112, 30 illus., 1 table, 12 equations.

Stress Analysis and Structures

Modern Wooden Construction. A. R. Weyl. Past experiences in wooden construction for aircraft are outlined for the benefit of those who are taking up aircraft work of this type in these days of emergency. Aeronautical timbers and their workshop qualities are surveyed including: sitka (or silver) spruce; ash; walnut; birch; Honduras mahogany; Douglas fir (Columbian Pine, Oregon Pine); Polish (Baltic) pine (Baltic redwood or Baltic yellow deal); shagbark hickory; beech; alder; Afara or "Noyer Limbo" (Cameroons walnut, Noyer de Cameroun); Port Orford cedar (Lawson cypress); Okoumé (Gaboon mahogany); tulip tree (yellow poplar or canary wood); Canadian black poplar (cotton wood); and balsa wood. Timber defects and inspection are also considered. To be continued. *Aircraft Engg.*, June, 1940, pages 187–188, 190.

Solid Organic Materials. N. A. De Bruyne. Characteristics of cellulose are discussed in detail including: molecular structure; micellar structure; cellular structure; wood as expanded cellulose; the swelling of wood; the gluing of wood; stress-strain curve for wood; strength of wooden beams; and the problem of jointing in regard to nails, surface dowels, and local reinforcements. Illustrations include: part of the cellulose chain shown conventionally and in model form; molecular-chain diagram; "brick-wall" picture of cellulose; model showing why cellulose fibres swell more across than along the grain; model of the micellar structure that is less crude than the "brick-wall" one; relation between porosity and apparent specific gravity of a wood; apparent density of balsa and lignum vitae indicating that that of balsa is less than one-tenth of that of the lignum vitae; average values for moisture contents of timber for various purposes; markedly curved stress-strain curve of wood in compression and the idealized curve enabling satisfactory relations for the strength of wooden beams to be obtained; relation of swelling to specific gravity; Prager's method of designing a wooden spar; and characteristic types of failure of material weak in shear. Continued. *Aircraft Engg.*, June, 1940, pages 177–180, 13 illus., 4 equations.

Plastics in British Planes. In a circular letter recently sent to British aircraft manufacturers by the Air Ministry it was pointed out that the designers should, wherever possible, use plastics in place of light alloys for lightly stressed as well as unstressed parts. The Air Ministry has been favorably impressed by reports from Farnborough regarding the ability of advanced experimental aircraft components to withstand stress and strain imposed by severe laboratory and flight tests. Reference is made to a new type of hardener for urea glue discovered by N. A. de Bruyne which enables the glue to bridge gaps in joints between surfaces as far apart as 0.020 in. and yet at the same time to produce a union of adequate strength. Resultant joints possess shear strengths above Air-Ministry requirements and fulfill the most stringent requirements.

New developments in the field of thermo-plastics are discussed, these being considered the most important materials by British aircraft designers. From the designer's standpoint one of the greatest assets of cellulose acetate is its ready adaptability for series production as opposed to mass production. In addition a shadow system of fabricators can be built up very quickly in factories and workshops not equipped for metal work. Use of thermo-setting resins such as Bakelite is also discussed. *Aviation*, July, 1940, pages 44–45, 118, 120, 4 illus.

Angle and T-Section Constants. Graph shows angle and T-section constants. Value of K for Z-sections about YY is equal to that of a T about YY. *Aircraft Engg.*, June, 1940, supplementary sheet No. S2b.

"Aeromold" Trainer. Method of manufacturing the Timm "oven-baked" plastic airplane is discussed. Fuselage is made in two halves which permits easy installation of seats and other interior fittings, and then the two halves are pressed in a precision mold and later baked. Former rings at various points complete the structure. *Aviation*, July, 1940, pages 56–57, 4 illus.

Why Plastics? J. P. Eames. Aeromold process consists of impregnating thin sheets of plywood with a phenolic resin bonder, molding them in a single operation into the desired components, baking the whole in order to attain the ultimate in both bonding and physical characteristics of the phenolic resin, and finishing with a plastic paint. Existing methods of metal aircraft construction are compared with the Aeromold method employed by the Timm Aircraft Corporation, and the latter is described. Reference is made also to the Clark Duramold method. *Western Flying*, July, 1940, pages 15–16, 23, 2 illus.

Aircraft Accessories

Tricycle Undercarriage Design. P. B. Walker. Inertia loading actions for the modern landing gear are analyzed. First objective of the paper is to give the designer a general indication of the loads that may be expected and the energy absorption required. With this is included an attempt to set an upper limit to these quantities by consideration of somewhat extreme cases. These might well be considered too severe, at least in the case of the front wheel, but the designer can always introduce an empirical multiplying factor based on experience and his intuition. Cases considered comprise landings on the front wheel only, landing on the rear wheels only, and an even landing on all wheels on the assumption that there is no angular acceleration in pitch during the contraction of the oleo legs.

Second objective is to make use of knowledge of the general behavior of tires and oleo legs acquired by experience with orthodox undercarriages and conventional drop tests. For the purpose of assessing the required characteristics of a particular oleo system, the complex inertia system is represented by a "single equivalent mass," which is assumed to be placed at the top of the oleo leg and to descend initially with the velocity specified for the airplane as a whole. The complete range of cases investigated is represented in diagrams. Various conditions of ground drag are investigated, including landing with brakes applied, and landing on uneven ground (local slope). *Aircraft Engg.*, June, 1940, pages 171–173, 6 illus., 4 equations.

Bloctube Ball Lever Joint No. 1—A New Mechanical Joint. R. Tampier. Lever joint to replace forks and offset ball joints on controls is described. After the joint is pushed on the ball, the clip is turned and swung down, a

key locking the joint. Advantages claimed are no backlash, interchangeability, 70° angular movement, and weight 0.35 oz. When large loads have to be transmitted a long distance, connecting tubes are connected to "ball-tube joints" which permit the controls, instead of having longitudinal and lateral movements, to transform these movements into only one sliding movement, through a number of guides fitted on the transmission. Large illustration on one side of a supplementary sheet and description on the other. *Aircraft Engg.*, June, 1940, supplementary sheet between pages 190–191, 1 illus.

Aircraft Maintenance

R.A.F. Maintenance. R. E. Hautier, British Air Ministry. Detailed description of the system of maintaining aircraft and engines for the Royal Air Force, includes: work of the maintenance command; first maintenance problems which arise in the squadrons; squadron headquarters servicing party; maintenance in the field; mobility; specialization of maintenance personnel; maintenance of trainer aircraft; aircraft repairs *in situ;* major overhauls of airplanes and engines; the Nuffield scheme; service manned repair depots; and storage units. *Aviation*, July, 1940, pages 42–43, 102, 2 illus.

Aircraft Manufacture

The Aeronautical Industry of Germany in Wartime. P. H. Monand. A new metal is now used in Germany which, freshly hardened, is more malleable than duralumin. It can be worked without aging in the course of the 12 to 24 hours which follow its treatment. After this period, the shearing strength of the new metal would be weakened by only 10 per cent.

Declaration of an Austrian firm, which pretended to produce Me.109 airplanes from products 100 per cent purely German, was false. The record is held by the Arado airplane in which 88.2 per cent of the materials are specifically German. It has been confirmed by the intelligence service that the possibilities of production of the German aeronautical industry, in regard to machines and tools, are not entirely utilized. For example in the Erla group of factories, situated in Saxony near Erzgebirge, not far from the old Czechoslovakian frontier, the workers work only 8 hours per day, and married women only 5 hours. These factories are auxiliary plants producing the Messerschmitt Me.109 fighter with the Daimler-Benz 1150-hp. engine. Machine tools and hand work in other plants and production in the Saxony plant are discussed. *Les Ailes*, May 16, 1940, page 6, 2 illus.

The Camera Aids New Lofting Technique. Particularly adaptable in the loft, the process developed by the Glenn L. Martin Company employs an heroic-scale camera which reproduces engineering drawings directly on wood, metal, cloth, paper or other surfaces. Where an experimental airplane is to be built, the master drawings can be photographed directly onto the metal of which the ship is to be constructed and the parts cut directly from the material itself. If a wind-tunnel or water-basin model of a projected airplane is desired, it is only necessary to use the camera to scale down the lines instantly from full size to any desired proportion.

Camera is set up to take photographs of large drawings, the negatives are developed, and the images projected back to large sheets of aluminum alloy, surfaces of which have been sensitized with a special emulsion. When such a sheet (maximum standard size used is 10 × 5 ft., but larger sheets could be handled) is placed in developing tanks, the drawing appears on the surface in exact size, or in fractional or multiple scales, as desired. Description of process. *Aero Digest*, July, 1940, pages 64, 67, 6 illus.

Can We Produce Airplanes by Stamping? E. V. Crane, E. W. Bliss Company. To have airplanes in the quantities we need, it is necessary: to choose a limited number of producible models; to allot quantities sufficient to win hands down; to organize our toolmaking facilities to get going at once on fitted dies (hard or soft); to use intermediate and mass production methods which do not require skilled workers; and to get the metal rolled, blanked, stamped, and assembled. The great 3000- and 5000-ton-capacity hydraulic presses are an astonishing development of American airplane builders. Details of these presses, methods of airplane production compared with those of automotive production, and the cutting of sheet-metal blanks are discussed. *Aero Digest*, July, 1940, pages 36–38, 6 illus.

Delaying Age-Hardening of Duralumin—A Study of the Use of Refrigeration. J. C. Arrowsmith and K. J. B. Wolfe. Industrial process described is used for delaying the age-hardening effects in Duralumin sheet and rivets for a sufficient time after solution heat treatment to enable normal production to take place. Special feature of the method is the provision of a low-temperature quench tank which eliminates the long period usually needed for the material to reach the refrigerator conditions. Discussion covers: reheat treatment as a hindrance; increased aircraft production; mass production of panels; cost of operating heat-treatment furnaces; influence of temperature; preliminary hardness tests; practical application; construction of refrigerated store; excessive cooling times; and choice of quenching medium. Institute of Metals paper. *Metal Industry*, July 5, 1940, pages 3–6, 3 illus., 2 tables.

Delayed Age-Hardening. J. C. Arrowsmith and K. J. B. Wolfe. Investigations into the use of refrigeration to speed up the production of large duralumin aircraft pressings are described, including: duralumin pressings; limitations of heat treatment; influence of temperature on rate of age hardening; effect of decreasing the temperature; practical applications; and refrigerated store. Alclad sheet took practically twice as long to cool as the duralumin, a fact which is attributed to the more highly polished surface of the former. By storage in a refrigerator operating at a temperature of −6° to −10°C. (15° to 20°F.) normalized duralumin sheet blanks may be kept for periods up to four days without age hardening taking place to such an extent as to interfere with cold-pressing operations. *Aircraft Production*, July, 1940, pages 225–226, 1 illus., 2 tables.

Developments in Drop Hammer Dies. W. W. Broughton. Development, production, and applications of Kirksite A, a new zinc alloy used in drop-hammer dies for the aircraft industry are discussed, including: Kirksite punches; blanking and piercing dies; sand-cast blanking and forming dies; patterns of Kirksite A dies; sand molding; casting Kirksite; reduction of warpage; and finishing the die. Physical properties of rolled Kirksite "A" sheets are given in a table. Photographs show various examples of combination dies of Kirksite A, and the blank die and magnetic die set developed by Consolidated Aircraft Corporation. *Aero Digest*, July, 1940, pages 56, 59–60, 135, 4 illus., 1 table.

Engineering Design for Die Casting. H. L. Harvill. Recommendations are given for the design of die-cast parts, and die-casting dies, finishing and assembly of die castings are also considered. Data on brass, aluminum, zinc and magnesium alloys are given in tables. Examples of various die-cast aircraft parts as well as some of the processes are illustrated. *Aero Digest*, July, 1940, pages 39–40, 43, 111–112, 9 illus., 4 tables.

Men and Machines. Descriptions of new machines of interest in automotive and aircraft manufacture, and abstracts of the *S.A.E.* paper "Surface Finish Control in Machine Shop Practice," by R. F. Gagg of Wright Aeronautical Corporation, and of the book "The Story of Superfinish," by A. M. Swigert, Jr.

Two new accessories and a new instrument modification, developed by Physicists Research Company, and said to greatly extend applications of the Abbott Profilometer measurements of surface, include the Motortrace for mechanical operation of the tracer, the Type I tracer for measuring roughness inside holes down to 1/2 in. in diameter, and One Microinch Scale which is three times as sensitive as the standard Type P Profilometer. New profiling machine of the National Broach and Machine Company is very rapid, entirely automatic, and holds finished work to a tolerance limit of 0.002 in. All-steel press brakes of E. W. Bliss Company have a capacity of 1/4 in. by 12 ft. mild steel. Other machines described include: the Progressive electronically-controlled gun welders, and new two-gun portable spot-welding unit; "Gearbroacher" developed by the American Broach and Machine Company; and Incolap gear finishing and correcting machine developed by Gear Processing, Inc. A brief résumé of other developments in machine tools and allied equipment is also given. *Automotive Industries*, July 15, 1940, pages 56–59, 67–69, 11 illus.

New Equipment. Progressive portable heavy-duty welding outfit. Aircraft Tools ball bearing stop countersink. Ajax-Hultgren aluminum-alloy heat-treatment units. Arcmaster all-metal arc welder. Williams auxiliary wrench-set kit. Farnham mill countersinking machine for work on flush rivets. Hydraulic Press vertical-type plastic injection-molding press. Walker-Turner radial cutting machine for wood, plastics and metals. Scotch Wetordry masking tape. Aeronautical Trading engine-cylinder baking oven. Hannifin No. 10 toolroom machine combining precision lathe, sensitive drill press, and horizontal and vertical milling machine. Harnischfeger P & H-Hansen WD-150 small welder with wide range. Oilgear propeller-blade-twisting machine. Short descriptions. *Aero Digest*, July, 1940, pages 172, 175–176, 179, 7 illus.

Role of Bending Presses in the Manufacture of All-Metal Aircraft. C. L. Peterson. Machine described is used in punching 150 holes ranging from 0.078 in. to 0.250 in. in size at one time, clearance between punch and dies being held to 0.0015 in. to avoid burrs. A bending press is also described which is used to punch individually holes of 5-in. diameter in 12-gage plate and holes up to 8 in. in diameter in 10-gage plate. Other machines for making corrugations and a great variety of bends are discussed. Some of the types of bends which may be performed on bending presses are illustrated in a drawing and a table gives ratio of die width to plate thickness for No. 20, No. 16, No. 12, and No. 10-gage plate and for plates from 3/16 in. to 1 in. thick. *Iron Age*, July 25, 1940, pages 37–39, 4 illus., 1 table.

Rolling Corrugated Sheet. Unique rolling machine specially developed for rolling corrugations in 24SRTAL aluminum-alloy sheet at the Douglas Aircraft Company is described. Types of corrugations formed on the rolling machine are illustrated in drawings and the advantages of the Douglas type of corrugations over other types are discussed. *Aero Digest*, July, 1940, pages 88, 91, 9 illus.

Value Received from an Engineering Department. H. L. Hibbard. Further description of the Engineering Department of Lockheed Aircraft Corporation including: job specifications for senior detail draftsman, senior layout draftsman, junior stress analyst, senior group engineer, and project engineer; preliminary project time estimate; group estimate; final project time and cost estimate; preliminary design schedule; final design schedule; and structure analysis and research. *Aviation*, July, 1940, pages 46–47, 104, 106, 3 illus.

Stinson's New Factory Now in Full Operation at Nashville, Tenn. New plant comprises a 122,914-sq. ft. factory building, 20,228-sq. ft. office building, and auxiliary buildings consisting of paint shop, paint storage, wood shop and hammer room, and a sand-blasting unit located between the fabricating department in the main building and the paint shop. Description of factory. *Aero Digest*, July, 1940, pages 84, 87, 112, 6 illus.

Aeronca's New Factory at Middletown, Ohio. Slightly more than 300 ft. long and about 200 ft. in depth, including the two wings on the south, the factory provides Aeronca with 60,000 sq.ft. of manufacturing floor space. Description of factory and production methods employed. *Aero Digest*, July, 1940, pages 116, 118, 120, 14 illus.

Drawing Alclad Strip. Recent investigation carried out by the Northern Aluminium Company on the drawing of Alclad strip for aircraft components is reviewed. Rectangular section, profile of which was partially open on one side, exhibited a tendency to crack during drawing. It is said that aluminum coating on Alclad alloys behaves in a different way from the harder surface of the uncoated high-strength alloys, and the lubricating effect of the aluminum coating greatly facilitates the production of components such as an aircraft fuel tank. Investigation determined that cracking had emanated from a notch in an extreme edge of the section, undoubtedly due to the fraying caused by excessive crowding of the die at the edge of the sheet. It was recommended that the lead radii at the back of the die be made more liberal and that the sizing surface, the lead radii, and all draft surfaces be given a high polish. Adoption of these recommendations resulted in complete elimination of the trouble. *Light Metals*, July, 1940, page 168.

Short discussion. *Aeroplane*, June 28, 1940, page 866.

Men and Machines. Various types of machine tools available for automotive and aircraft production are described and illustrated. *Automotive Industries*, July 1, 1940, pages 28–30, 45–47, 8 illus.

Notes on the Forming of Aircraft Structural Components. Example of the bending of light-alloy sections to the profiles required for modern aircraft construction is described. An extruded T-section (2 × 2 × 1/4 in.) of aluminum alloy NA.26S, produced by the Northern Aluminium Company to meet DTD.364 was required to be bent into an airfoil profile for use as a wing member in a large aircraft. Chemical composition specified in DTD.364, and minimum mechanical properties guaranteed for NA.26S to DTD.364 and average figures obtained are shown in a table. *Light Metals*, July, 1940, page 186, 2 tables.

Shop Equipment and Small Tools. Some modern aids to British aircraft production are described, including: Hansen portable sandblast gun; Marconi-Ekco meter for the rapid testing of moisture content of timber; Bausch and Lomb toolmakers' microscope specially designed for optical inspection under workshop conditions; Procunier tapping attachments incorporating a highly sensitive friction clutch to reduce danger of tap breakage; Consolidated No. 3005 power vane drill; Salford electro-magnetic fatigue tester for steel bars and non-magnetic metals; and new Lincoln transportable engine-driven welding machine. *Aircraft Production*, July, 1940, pages 223–224, 7 illus.

Some Notes on Heinkel Production. H. J. A. Wilson. Development of the Heinkel He.111 from the first conception of the designer to the delivery of the finished machine to the Luftwaffe is the subject of a recent book "Schmiede der Luftmacht" by G. Jaeckel. Survey presented is an extract from the last chapter of the book describing the mass production of this airplane at Oranienburg. When the German aircraft industry began serial production of military airplanes, it was found that existing works could only

be extended with great difficulty. It was therefore decided to build separate mass production factories. These new factories were laid out and organized according to a uniform scheme, differing only in regard to size of buildings, which varies according to the measurements of the class of airplane under construction. Each of these factories consists of five main buildings, spread over a large area.

Complicated panels, such as engine cowlings or wing-root fairings, are still laboriously manufactured by hand. Turning, planing, and milling processes are replaced by pressing, forging, or casting. Layout of the Oranienburg works is shown in a drawing and processes taking place in each building are described in detail. Photographs show various operations on the aircraft during production. A photograph of the complete engine and mounting unit calls attention to the typical cast magnesium-alloy cantilever bearer which, in conjunction with the inverted engine, allows exceptional accessibility. *Aircraft Engg.*, June, 1940, pages 183–186, 18 illus.

Spot Welding of Dural Sheet. Blumrich, Gotha. The detrimental arrangement of the test pieces which in tensile tests are never stressed purely on shearing (tension, bending) leaves it to be expected that, in the arrangement of several spots at sufficiently great distances, greater strength is obtainable. It is impractical to make the diameter of the weld large, as this would necessitate high current intensity. A lower limit is given by the required minimum pressure of the electrodes. A most efficient range of the electrode diameter lies between 6 mm. and, at the most, 8 mm. It is then possible to work with considerably lower current intensities. For continuous operation it must be calculated with much lower strength values than in the case of individual welds. For one continuous run, a table shows, for sheet thicknesses of 0.6 to 1.2 mm., the regulating quantities (electrode pressure, welding time and degrees) which require no excessive heating of the electrodes for the most efficient strength values. Table also gives the shearing load of spot welds for each sheet thickness.

Results of spot-welding tests on dural sheets of conventional thickness are reported. Effects of the individual variables are investigated and discussed. The suitable regulation for continuous operation with the proper strength values are presented. Photographs show the welding installation of the Fa. Paul Knopp, and microsection of a spot weld in 1.2-mm. sheet at 130-kg. electrode pressure. Drawings and graphs cover: test form; electrode inserted in the holder which is inserted in the machine, enabling the use of a small electrode and the saving of material; relation between current intensity and welding time, and between welding time and pressure; effects of electrode pressure on the welding zone and of the electrode diameter on the strength of the spot; relation between current intensity and pressure; and diagrammatic sketch of the welding spot cut open. *Luftwissen*, April, 1940, pages 96–100, 11 illus., 2 tables.

Aircraft Patents

Trend of Invention. Title, owner, and number only of United States patents of interest to the aeronautical industry. *Aero Digest*, July, 1940, page 187.

Aircraft Performance

Compensation of the Flight Speed According to the Method of Least Squares. M. Miller. For the determination of the relative speed V of an airplane, the speeds are determined over ground for the outward and return flights over courses P_1P_2 and P_3P_4, the directions of which form the angle φ to each other. From the point 0 the four determined speeds V_{12}, V_{21}, V_{34}, and V_{43} are settled in the proper direction. This measuring method is subject to a number of inaccuracies. For example, during the duration of the measured flight, the wind speed or its direction may vary. These errors become apparent when the four points A, B, C, and D are no longer exactly on a circle. From elementary geometry it is known that a circle with reference to the position of its center point and magnitude of its radius are clearly defined by three points not in a straight line. Therefore, in the case under discussion, one of the four speed measurements is unnecessary. The values of V_{12}, V_{21}, V_{34}, and V_{43} therefore should also be so improved that the terminal points of the corrected course are exactly on a circle. The compensated courses developed by the addition of the correction v to the V values are given, and the close compensation and logarithmic compensation are shown with a numerical example. *Luftwissen*, April, 1940, pages 113–114, 1 illus., 12 equations.

Aircraft

Some Ideas on the War. Major A. De Seversky. As regards defensive armament, the British bombers are placed first and American bombers second, with those of France and Germany third, together. The author considers that the Spitfire is the best fighter airplane at present in service. However, it has not the easy accessibility for maintenance possessed by the Messerschmitt, and in inverted flight the Rolls-Royce engine cuts out. The Messerschmitt, on the contrary, remains perfect in any flying position. Comments are made on the necessity for escort fighters, on the need for defensive armament for bombers, and on the designs of the Spitfire and Messerschmitt. The opinions are expressed that the only military machines that will remain in the air in the daytime will be long-range pursuit aircraft, and that bombing forces will confine their operations to the night, or to days when bad atmospheric conditions prevail. Translated from "L'Ala d'Italia." *Flight*, June 20, 1940, pages 545–546, 546a, 4 illus.

FRANCE

The Ambrosini Racer: 405Km./Hr. with 240 Hp. Events did not permit the announcement of this airplane which on August 27, 1939, is said to have raised to 392.584 km./hr. the world record for speed over 100 km. for airplanes in the first category (engines of 6.500-liter to 9-liter cylinder capacity). The Ambrosini monoplane has a low wing of one piece, built entirely of wood with three spars. Powdered with a 240-hp. Hirth engine driving a variable-pitch propeller, the airplane attained 405 km./hr., and has a landing speed with flaps lowered of 100 km./hr. The airplane takes off in 220 meters and is landed in 150 km. Wing span 9 meters. Weight empty 750 kg. Total normal weight 1200 kg. and, with overload, 1375 kg. Short description, characteristics and performances. *Les Ailes*, May 23, 1940, page 4, 1 illus.

GERMANY

The Enemy Has Put New Airplanes in the Line. Some details of the following new German airplanes: Messerschmitt Me.115 combat airplane (Daimler-Benz 1200-hp. engines); Dornier Do.215 combers (D.B.603 1500-/1700-hp. engines); Heinkel He.113 fighters resembling the He.112U single-seater, and placed in service on the Norwegian front.

This article is similar to an English article in *Flight*, May 30, but is longer and gives a photograph and more details, especially of the He.113. *Les Ailes*, May 23, 1940, page 5, 1 illus.

Heinkel-116 Auxiliary Airplanes. A. Frachet. Designed originally to answer the needs of commercial aviation, the 7-ton four-engine He.116 (four Hirth H.M.-508B 240-hp. engines) is utilized in the war as a reconnaissance airplane and as a magnetic mine layer. Its efficiency is interesting but its performances are very low if one compares them to those of modern military airplanes. The He.116 possibly served as a flying model for the large four-engine He.119. Movable load of the He.116 is 2830 kg., which leaves an appreciable margin for the disposable load for bombs, if range of flight is reduced to 2250 km. Wing span 22 meters. Maximum range 4500 km. with four reservoirs filled with 2600 liters of fuel. Ceiling 7000 meters. Maximum speed 370 km./hr. *Les Ailes*, May 16, 1940, page 5, 3 illus.

Messerschmitt Jaguar Fighter. Fighter is for long-distance use, carries a crew of four men, and is armed with several light and heavy machine guns. Cantilever wing of Messerschmitt all-metal construction has slotted trailing-edge flaps with hydraulic operation. Fuselage is of semimonocoque construction with a full-view observation station in the nose, and cantilever tail surfaces with endplates as vertical control surfaces. Landing gear and tail-wheel are retractable hydraulically. The Jaguar is powered with two water-cooled engines. Photograph and brief reference only. *Luftwissen*, April, 1940, page 93, 1 illus.

ITALY

Italy's Air Force. For articles on the characteristics and performance of Italian airplanes see the following: *Luftwissen*, April, 1940, page 126, 1 illustration, 2 tables; *Flight*, June 20, 1940, pages 540, 541, 3 illustrations; *Flight*, June 27, 1940, pages 562a–562d, 563, 15 illustrations; *Flight*, July 4, 1940, pages 12–14, 19 illustrations; *Flight*, July 11, 1940, pages 24b–24d, 25, 10 illustrations; *Flight*, July 18, 1940, pages 45–48, 12 illustrations, 2 tables; *Aeroplane*, June 28, 1940, pages 856–857, 10 illustrations; *Aeroplane*, July 5, 1940, pages 22–23, 8 illustrations.

U.S.A.

Yankee Warplanes Over There. L. Engel. Advantages and limitations shown by American-built bombers and pursuits operating in Europe, in comparison with Allied and German aircraft, are pointed out. Criticisms are directed at the lack of gunpower and armor protection for the pilot on fighters, and at sliding cockpit cowls. Maneuvers which the French have worked out with the P-36 are briefly described. The need for identification of airplanes "into which Air Corps experts might look" is emphasized. *Popular Aviation*, August, 1940, pages 16–18, 86, 5 illustrations.

The Piper Cub Coupe. Cutaway drawing of the Piper Cub airplane showing construction, and a few details of characteristics and performance.

On other pages are photographs, characteristics, performances, and equipment of the Beechcraft F17D and 18S, Cessna T-50, and Howard DGA-15P. *Popular Aviation*, August, 1940, pages 41, 50, 51, 6 illus.

Aeronca "Super-Chief" for 1941. Super-Chief is a two-place side-by-side high-wing monoplane available with either the 65-hp. Lycoming or the 65-hp. Continental engine. Wing span 36 ft. Maximum speed 109 m.p.h. Landing speed 38 m.p.h. Cruising range 350–500 miles. Long description, characteristics and performances. *Aero Digest*, July, 1940, pages 122, 124, 5 illus.

Aviation Sketch Book of Design. Detail drawings are presented with explanations including: the landing gear of the Howard 1940 model; a 0.30-caliber gun installed in the wing of a Republic EP-1 pursuit and capable of carrying 1000 rounds of ammunition; non-retracting type of tailwheel on the Howard 1940 model; tailwheel of the Model 18 twin-engine Beechcraft; and main landing gear of the Boeing Stratoliner which is of a single-strut oleopneumatic type and retractable within the inboard nacelles. *Aviation*, July, 1940, pages 54–55, 5 illus.

The Culver Cadet. Model L-CA Cadet low-wing two-place biplane is powered by a Continental A-75 engine, but is undergoing tests with Lycoming 75 and Franklin 80 engines. Wing span 26 ft. 11 in. Maximum speed 140 m.p.h. Stalling speed 45 m.p.h. Rate of climb 800 ft./min. Cruising range 600 miles. Description of structure, specifications, and performances. *Aero Digest*, July, 1940, page 71, 4 illus., 1 table.

The Sikorsky Helicopter. The VS-300 experimental helicopter is described. Drawings show the heart of the control of the two horizontal tail rotors, which lies in a mechanism directly behind the pilot's seat, and how the pitch of the three propellers located at the tail is varied by cables from the cockpit. Photograph shows a blower located behind the engine and supplying the cooling air. Drive belts from the engine are connected to the free-wheeling arrangement which allows all the rotors to rotate freely when not being driven. By a gearing arrangement the main rotor is directly connected to the three tail rotors. Main rotor, diameter 28 ft., and r.p.m. 255. Auxiliary rotors, diameter 6 ft. 8 in. and r.p.m. 1700. Gross weight 1150 lb. Four-cylinder Lycoming 75-hp. engine. Power loading 15.3 lb. Main rotor blade loading—average 51 sq.ft. Disc loading 1.86. *Aviation*, July, 1940, pages 65, 122, 4 illus.

U.S.S.R.

Soviet 64-Seater Airliner. The L-760, said to be the largest landplane in the world, has been put into regular service on the line Mowcow-Mineralniye Vody (Caucasus). Its flying weight is 46 tons (103,00 lb.), and it has a crew of ten. Wing span is 210 ft. Its six engines have a total power of 8000 hp. and range is 1864 miles. It has a ceiling of 23,000 ft. and a maximum speed of 186 m.p.h. Comparison with the Douglas B.19 bomber of same wing span and a loaded weight of 70 tons leads to belief that the 46 tons quoted is tare weight and not loaded weight, as the corresponding figure for the B.19 is given as 42 tons. Brief reference. *Flight*, June 20, 1940, page 544. See also *Aviation*, July, 1940, page 62, 2 illus.

Aircraft Assisted Take-Off

Assisting Take-Off and Alighting. F. W. King. Hydroplane launching gear for stepless flying boats. Aircraft is mounted for launching on a float-supported structure similar to that of a twin-float seaplane. Extra thrust may be provided by any number of aircraft engines and propellers mounted on the floats. With the propellers placed immediately behind the wings of the aircraft, the indraught induces lift which, operating during the early part of the take-off run, enables the floats to hydroplane later. The "Crouch-Bolas" effect is obtained for the take-off run without any complication on the aircraft. Aircraft could be mounted for launching without external assistance. Floats of the launching gear provide convenient tankage for refueling, eliminating the use of a separate tender, and servicing operations could conveniently be performed from the floats.

Vacuum plates are applied to the undercarriage of the wings and are hinged on a line near the c.g. of the aircraft. It is possible for the pilot to control the attitude of the aircraft during the take-off run by the normal elevator control. Although speed and course of the launching gear are under

control of its attendant, take-off may be completely under control of the pilot. Porpoising and diving tendencies during alighting run may be obviated by making the hull long on the water line. Advantages to be gained in design of the flying boat by the assisting take-off and alighting, and military advantages are pointed out. Stages in operations of mounting and launching are illustrated and discussed. *Flight*, July 4, 1940, pages 7–8, 2 illus.

Aircraft Accidents

Bad Weather Flying Accidents Can Be Avoided. W. H. Beech. Because of a series of fatal accidents the C.A.A. has placarded Beechcraft biplanes for restricted speeds until a thorough investigation of all the factors has been completed. The Beech Aircraft Corporation believes that the fundamental problem is that of safety education for pilots. Practically all the fatal accidents involving Beechcraft biplanes happened to pilots untrained in instrument flying and who were not rated as qualified instrument pilots by the C.A.A. The accidents which occurred while these pilots were attempting to fly blind in bad weather are discussed. *Aero Digest*, July, 1940, pages 106, 108, 128, 2 illus.

Air Transportation

The Empire Air Routes. Italy's declaration of war prevents the British Empire air service from following its usual route, and at first prevented it from running at all. British Overseas Airways have now recommenced a once-weekly operation of the flying-boat route between Durban and Sydney via Kenya, Alexandria, Palestine, India and the East Indies. Quantas looks after the Australian end, and the New-Zealand service continues to run regularly across the Tasman. The regular London-Lisbon service via Bordeaux has been suspended but contact is maintained by nonstop flights when required. In addition to the Durban-Sydney route, the speedier Indian Ocean crossing from Mombasa to Australia, which was surveyed by Capt. P. G. Taylor last year in the Guba flying boat, would be possible. This route is considered and illustrated. Map shows how Italian territories threaten the normal British Empire route. *Flight*, June 27, 1940, page 562, 2 illus.

Looking Forward—Prolegomena for a Detailed Study of the Future of British Civil Aviation. H. R. Cox. First issue—Controlling authority must not only ensure that aircraft are as safe as the state of the art of aviation permits, but it must also seek to improve the standard. Directions in which efforts must be directed to improve inherent safety are pointed out in regard to: number of engines; structures; prevention of ice formation and fire; aerodynamics and flutter; and extraneous safety. Design initiative and policy are necessary to success. The all-wing airplane is proposed and the gain in performance possible by utilizing the wing for stowage is illustrated. Question of landplane or seaplane is considered.

Second issue—Duties of the civil research and development organization; nature of future aeronautical investigation in regard to aerodynamic, structural and engine design; engine size for a 200-ton aircraft; education and training of personnel; apprenticeship schemes; economics of aviation; operational economics; coordination of civil aviation control; survival of civil aviation in wartime; and conclusions reached. Concluding installment of Wilbur Wright Memorial Lecture of the Royal Aeronautical Society. *Flight*, June 20 and 27, 1940, pages 549–551 and 564–566, 572d, 13 illus.

Extraneous safety; accident investigation; finance; internal economy; suggested system for coordination of the constituents of civil aviation through a controlling authority; and civil survival in war time. Concluded. *Aeroplane*, June 28, 1940, pages 860–861, 1 illus.

Propellers

Airscrew Blade Stressing. J. L. Taylor. By the assumption of a standard distribution of load, it is possible to calculate very rapidly the corresponding resultant aerodynamic bending moment at any given fraction of the blade radius. Numerous detailed calculations show that the error involved in this assumption is quite small for blades of normal form. The bending-moment curve, being the second integral of the load curve, is not very sensitive to detail changes in the shape of the latter such as may occur from blade to blade.

The statement that the resultant of the bending moments at the roots of all blades is simply the torque applied to the propeller by the engine, becomes exact if the blades are regarded as extending to the axis of rotation, as shear force acting on the blade section does not then contribute to torque. Working back from the torque, whose value is known, the method gives directly a resultant aerodynamic bending moment acting on an imaginary section at the shaft axis. Moment at the actual blade root or any other section is derived by multiplying by a coefficient, whose value at the particular fraction of the blade radius is known for the assumed standard loading curve. In passing from torque to axis bending moment, it is necessary to introduce the pitch angle. *Flight, Aircraft Engr. Sup.*, June 27, 1940, pages 27–28, 1 illus., equations.

Study of Airscrews for High Speed Aeroplanes. L. Lazzarino. Corrections are given for a number of errors in printing which were made in the original article appearing in the July 1939 issue of *L'Aerotecnica*, and which were therefore included in the translation published in the previous issue of the Journal. Translation from *L'Aerotecnica*, November–December, 1939. *Royal Aeronautical Soc., Jour.*, June, 1940, pages 546–548, 3 illus., 1 table, equations.

Ash Variable-Diameter Propeller. In the propeller patented in England by M.T. Ash, blades would be constituted by the telescopic elements connected by cables and compensating springs to the propulsive axis. Variation of the diameter would be automatically obtained by the centrifugal force and it would involve equally a change of propeller pitch, a change arising, it seems, from development, under a new angle, of the telescopic elements of the blades. Brief reference only. *Les Ailes*, May 16, 1940, page 9, 1 illus.

McCauley Steel Propeller Blade. McCauley solid steel propellers, now standard equipment on U.S. Army Air Corps training planes, are described. *Aero Digest*, July, 1940, page 111, 1 illus.

Acoustics

The Acoustical Impedance of an Infinite Hyperbolic Horn. J. E. Freehafer, M.I.T. In the discussion of the acoustical properties of a horn in the form of an hyperboloid of one sheet, it is possible to avoid the assumption of plane waves and to obtain an exact solution to the problem. The analysis, carried through with the aid of the differential analyzer, leads to curves representing the acoustical resistance and reactance as functions of the ratio of the radius of the throat to the wavelength. Comparison with the conical horn shows that the hyperbolic horn is superior. *Acoustical Soc. Am., Jour.*, April, 1940, pages 467–476, 7 illus., 18 equations.

The Attenuation of Sound in Tubes. R. Rogers. Method of calculating attenuation coefficients of sound in a tube lined with an absorbing material. While these are only first approximations, experimental evidence has been presented to show their validity for a large number of cases met with in practice. Theory presented treats only rectangular tubes, but the approximate expressions are equally valid for circular tubes. Results are found to agree with the previous work of Sivian for low frequencies. Present analysis also covers high frequencies and a formula is obtained. Wave equation is solved subject to suitable boundary conditions on the walls of the tube. *Acoustical Soc. Am., Jour.*, April, 1940, pages 480–484, 5 illus., 20 equations.

Aircraft Instruments and Navigation

Little Robot. R. Martin. Automatic pilot being developed for light airplanes weighs only 5 lb. It is built around the operation of a conventional turn and bank indicator from which the ball bank has been removed. Glass face has been replaced by a small rotary valve operated by the pointer of the turn indicator. Action of the turn indicator directs a vacuum supply, either venturi- or vacuum-pump actuated, to a piston installed in the lower part of the rudder. Turn indicator operates this power piston which in turn is connected to a tab on the rudder. *Popular Aviation*, August, 1940, pages 27–28, 4 illus.

Aircraft Navigation

The Ideal Flying Map Scale. F. Chichester. Today a flight map must be suited for a speed of four miles a minute and for a distance of 500 miles. A map to the scale of 1:3,000,000 and featuring rivers, mountains, and airports is recommended. It is thought that the scale for aviation of the future will be between 1/1,500,000 and 1/2,000,000 (between 20 and 30 miles to an inch). The pilot's dilemma in identifying his position, the need for elimination of unnecessary detail, and the merits of the 1/2,000,000 map are discussed. It is said that the more country covered in a sheet (within reason), the clearer the picture and assessment of the flight route, and that there is great advantage in having the whole flight on one sheet both for planning before flight and for study during it. The author's experiences in navigating during flights in China and Indo-China are described. *Aeroplane*, July 19, 1940, pages 61–62, 2 illus.

Position Finding by Planets. Lt. Comm. P. V. H. Weems. Convenience of working planet lines of position with the use of the "Air Almanac" is pointed out, and comments of a navigator of Pan American Airways are given. *U.S. Naval Inst., Proc.*, July, 1940, pages 967–968.

Armament

German Aircraft Armament—Bombs and Bomb Release Gears. The five bomb types used by the German Air Force have been designed for mass production rather than for aerodynamic efficiency, and their cylindrical form with square fins is inferior to that of British bombs. Construction is simple. In addition to these five types of bombs and one or two types of torpedo, Germany is known to have some bombs up to 1000 kg. for use against warships.

The five types of bomb, the fuses fitted, and vertical and horizontal bomb-release gears are described in detail. Tables give characteristics for 10 horizontal and 10 vertical bomb release gears. *Aeroplane*, July 5, 1940, pages 12–14, 18 illus., 2 tables.

Electrical Equipment

Electrical Switching for Aircraft. A. L. Riche. Need for, and requirements of, automatic switching for aircraft controls are discussed, and the Type H Micro Switch designed for aircraft used is described. *Aviation*, July, 1940, pages 70, 122, 2 illus.

Fuel Systems and Tanks

Aircraft Fuel Systems. J. Haworth. Design of an efficient fuel system is discussed in regard to number and disposition of the tanks, tank design, layout of pipes, cross feeding of fuel, especially in a four-engine aircraft, and safety considerations. In one method of joint design, a strip of rubber is laid between the two sheets forming the tank, and the whole joint then riveted up. Tank when finished is passed into an oven and slowly baked, during and after which, the rubber swells and develops a permanent enlargement. Swelling of the rubber causes a pressure to be exerted on the sheets forming the joint, thus ensuring a perfectly sound gasoline-tight joint.

The problem of vapor lock was solved in one case by insertion of the fuel pump into the fuel tank itself, so that there was absolutely no suction line and no suction head to overcome and the probability of vapor bubbles forming within fuel pipes was reduced to a minimum. It is suggested that all suction lines be as short as possible, and that all long horizontal pipes, inverted U bends and varying sections should be avoided. Also all fuel supply pipes should be as cool as possible. Drawings show: section through a De Bergue riveted type of joint; joint faces of a tank treated with special rubber solution; how the contents of one tank can be transferred to other tanks; and how fuel can be transferred from other tanks when one tank is holed. *Flight*, July 18, 1940, pages 44e–44f, 4 illus.

Experience in Integral Aircraft Fuel-Tank Construction. F. C. Albright. Experience of the Vought-Sikorsky Aircraft in the development of its present type of integral fuel-tank construction. Tests made with one type of tape in a seal subjected to aviation gasoline at pressures up to 100 lb./sq.in. showed that the tape was not plastic enough to fill in small irregularities in the sheet or extrusions forming the joint, but that rivets with a washer of this tape inserted under the head did not leak. Experience gained in this work led to the successful method whereby a uniform thickness of cement is applied to the tape instead of to the tank surface. This cement-coated tape has the desirable feature of expanding a greater amount than any of the materials tested when in contact with the gasoline.

Apparatus developed for pressure-testing various types of joints, rivet sealing, and corner blocks is described and illustrated. Drawings show: a special rivet, undercut at the base of the head to prevent Neoprene sheet washers from slipping from under the rivet; various types of rivets illustrating the method of using a washer of Du Pont No. 5005 tape inserted under the head; cross-section through apparatus used for applying cement to 5005 tape; and a fuel tank corner seal construction.

Spot welding has been used with success, one spotwelded tank having had three years of trouble-free service. This method is said to show cost savings on some tanks. *S.A.E. Jour.* (*Trans.*), July, 1940, pages 291–293, 5 illus.

Aluminum Aircraft Fuel Tanks. E. H. Dix, Jr. and R. B. Mears. Paper presented at the Annual Meeting, and previously abstracted from preprint. (See page 314, May issue of Journal.) *S.A.E. Jour.* (*Trans.*), May, 1940, pages 215–220, 2 tables.

Miscellaneous Equipment

Anti-Concussion Bandeau. Webflex concussion bandeau covers the frontal region of the skull, the temples, and the ear openings, and extends back to the base of the skull. It is made of soft aerated rubber (Dunlopillo cushioning) composed of millions of small intercommunicating air cells, each of which soaks up its portion of the blast in the substance of the rubber. Short description. *Flight*, July 4, 1940, page 18, 1 illus.

Seat Cushions and the Ride Problem. C. R. Paton, E. C. Pickard, and V. H. Hoehn. Proper balance between the car suspension and the passenger suspension, namely, the trimmed seat, should have a very definite relationship. The effect of seat pads, upholstery cloth and style, seat contour, and seat springs on riding comfort are shown, and the results of tests indicating the effect on ride of different combinations of these elements are presented. It is emphasized that actual contour of a seat cushion when the passenger is in it, is of chief importance and free contour is of little importance. Possibility of a leaf type of variable-rate cushion spring and a means for elastically suspending the seat assembly as a whole with respect to the car body are suggested. Machine for determining frequency and damping characteristics of cushion-spring assemblies is described and illustrated and results of tests are discussed. *S.A.E. Jour. (Trans.)*, July, 1940, pages 273–283, 27 illus., 2 tables.

Aerial Photography and Mapping

The Small Scale Air Survey Camera. G. S. Andrews. Experiences of the British Columbia Forest Service with the Williamson "Eagle III" aircraft camera are considered in regard to equipment, advantages of the small scale camera, work done, costs, photographs, vibration, and printing. Points which have come to light through experience and which might be of interest in designing a future small-scale camera are discussed, including picture format, ruggedness, film magazine, shutters, records, projection prints and "focal length," and interchangeable parts. *Photogrammetric Engg.*, April–June, 1940, pages 91–97, 1 table.

The Brock Process of Topographic Mapping. E. A. Schuch. Full-automatic type of camera used; ground control; enlarged glass positives; point marking; radial control; lens altitude computations; computations of parallax for tilt analysis; tilt analysis; correcting projector; final glass positives; computations of contour parallax; contouring; and scale equalization. *Photogrammetric Engg.*, April–June, 1940, pages 55–62.

Comparison of the Methods of Operation of the Multiplex Projector and the Aerocartograph. E. A. Shuster. Differences between the Multiplex and Aerocartograph are described, and disadvantages of the Aerocartograph are pointed out. *Photogrammetric Engg.*, April–June, 1940, pages 85–86.

Testing Apparatus

A Convenient Electrical Micrometer. R. Gunn, U.S. Naval Research Laboratory. Simple and stable electrical micrometer described is suitable for the measurement of zero or low-frequency displacements, and has wide application to instruments and to many problems of physical measurement. It provides a satisfactory electro-mechanical link for converting small mechanical displacements into accurately proportional electrical currents or potentials. In the vacuum tube employed, electrical constants are changed by a mechanical displacement applied to the end of a short rod. Hot filament provides a stream of electrons which flows to two insulated plates carried on a short rod and arranged for vertical movement by an arm through deformation of the vacuum-tight diaphragm. Resistance of one plate-filament circuit is increased while the other is simultaneously decreased. *Rev. Scientific Instruments*, June, 1940, page 204, 1 illus.

Materials

Adhesives and Cements for Metals. Nature and composition of a range of suitable compounds are discussed with data on the following: characteristics of liquid fish glues, of refined shellacs, and of ready-prepared shellac solutions; typical compositions of shellac-base cements and adhesives; characteristics of starch- or dextrin-base adhesives and of nitrocellulose-base adhesives or cements; typical formulas for casein cements and adhesives; typical compositions of celluloid adhesive solutions; characteristics of petroleum bitumens suitable for securing laminated metal-foil/fabric products, and of bitumen-base sealing paints; melting points of commercial waxes, paraffins, and refined ceresins; characteristics of air-drying Bakelite/rubber varnish adhesives, of Glyptal varnishes used for sealing gaskets, and of slow-drying elastic sealing paints of the pigmented synthetic type; and characteristics of Bakelite cement and varnish and of special rubber-base adhesives. Inclusion of unsuitable media, factors of availability and stability, solid cold cements, plaster fillers for glues, shellac products, aqueous starch-base adhesives, casein cements and advantages of casein glues, nitrocellulose cements, modified starch adhesives, bitumen fixatives, wax fixatives, paint and varnish adhesives, rubber fixatives, and the patented processes are taken up. To be concluded. *Light Metals*, July, 1940, pages 175–181, 16 tables.

The National Physical Laboratory. Review of research carried out during 1939 in the engineering department on metals and other materials, as well as in metrology, aerodynamics, ship testing, heat, radiology, sound, light, electricity, and radio. Summary of Annual Report for 1939. *Engineering*, June 28, 1940, pages 626–627.

Influence of the Further Technical Development of Aircraft Materials on Maintenance. W. Treibel. Improvement of existing aircraft materials, and the influence of the technical development of new aircraft materials. General discussion only. *Luftwissen*, April, 1940, pages 115–116, 2 illus., 2 tables.

Automotive Materials. New Union Maxcut Bessemer screw steel with physical properties comparable to SAE X1112, and new Union Multicut open-hearth screw steel with physical properties similar to those of SAE 1115, both produced by Republic Steel Corporation. New SAE 4815 carburizing nickel-molybdenum steel for heavy-duty gear and shafting applications and having machining properties comparable with SAE 4615 and SAE 2315 in respect to cutting speeds and finish. Soya-bean culture in Japan. Methods developed by the Bureau of Standards for reducing the corrosion of aluminum and magnesium alloys used in aircraft construction. Improved bonding process for babbitt-lined bearings, a recently patented French process, described by A. Portevin. New Scotch Wetordry masking tape having the advantages of no sweating, dead stretch, more flexibility, thinner construction, strong backing and adhesiveness.

Descriptions, long or short, of these materials and reference to new tests in Report on Standardization of Petroleum Products submitted to the A.S.T.M. *Automotive Industries*, July 15, 1940, pages 70–72.

Metals

Electrolytic Polishing in the Laboratory and in Industry. Experimental results obtained by Pellissier, Markus, and Mehl using the method of Jacquet and Rocquet; industrial applications; attempts at chemical polishing; the Allegheny-Ludlum process using phosphoric acid; characteristics of the finish; rustless process using a solution of concentrated citric and dilute sulfuric acids; and S. Tour's process employing a concentrated sulfuric and hydrofluoric acid electrolyte. *Metal Treatment*, Spring, 1940, pages 21–25, 1 illus.

Pickling and Polishing of Metals. S. Tour. Blaut-Lang process in which Lucius Pitkin has an interest is further discussed, attention being directed primarily to the process itself, its characteristics, operation, and future possibilities. *Iron Age*, May 30, 1940, pages 26–30, 2 illus.

Modern Assembly Processes—Their Choice and Control. J. L. Miller. Riveting by various methods such as hand forming, power presses, rolling, and mechanical hammering, as well as hot riveting by the use of the spot-welding machine are discussed. Photographs show satisfactory and unsatisfactory rivets, and tables give results of tests on tightness of joints produced by different riveting processes, results of shearing test on riveted strips, and squeeze pressures for rivets. *Metal Industry*, July 19, 1940, pages 42–46, 8 illus., 3 tables.

Corrosion and Protective Coatings

American Practice for Surface Treatment of Magnesium Alloys. Anodic treatment specified by the U.S. Navy for magnesium alloys used in naval aircraft, and nature of the coating produced are discussed. Directions given by the Dow Chemical Company for alternative treatments (Treatments Nos. 7 and 8) are described. These treatments correspond to U.S. Army and Navy specifications and may be used in naval aircraft work in place of the anodic treatment. Treatment No. 6 of the Dow Company, also described, is a caustic-pressure treatment for providing a decorative and corrosion-resistant finish on magnesium-base alloys. The possibility of dyed finishes is considered. *Light Metals*, June, 1940, pages 163–164, 1 illus.

Anodizing. J. M. Perfect. Processes available for the anodic oxidation of aluminum and its alloys, and some of their results, applications and difficulties are described, including: the Bengough-Stuart process developed at the National Physical Laboratories in 1923 and using a 3 per cent solution of chromic acid at 40°C. ± 2°C. as an electrolyte; sulfuric-acid processes, such as that patented by S. R. Sheppard in 1930 and approved by the British Air Ministry for the treatment of aircraft parts; and oxalic-acid processes, such as the Eloxal process used extensively in Germany. *Flight*, July 11, 1940, pages 32–34, 4 illus.

Practical Notes on the Dyeing of Anodized Aluminium. F. Hill. Essentials of the dyeing technique are presented, with special reference to suitable types of dye. Tables list light fastness of dyestuffs requiring no addition of agents to bath, and light fastness of light-fast acid dyes for anodic films. *Light Metals*, July, 1940, page 172, 2 tables.

Iron and Steel

Recent Trends in Corrosion-Resisting and Heat-Resisting Steels. J. H. G. Monypenny. Recent developments are surveyed with particular attention to the following: effect of nitrogen in high-chromium irons; the addition of copper to martensitic steels; the free-cutting stainless steels; variations in composition of austenitic steels; intercrystalline corrosion; chromium-manganese austinitic steels; and the development of brittleness as a result of the formation of the phase based on FeCr. Alternations in composition that appear to confer immediate advantages by improving the mechanical properties may give rise to trouble in the long run by promoting the formation of the brittle constituent during prolonged heating at high temperatures. *Metal Treatment*, Spring, 1940, pages 3–7, 10, 1 table.

Nonferrous Alloys

Age-Hardening Magnesium Alloys. W. F. Chubb. Equilibrium diagram of the thallium-magnesium system, determined by Grube; conductivity isothermals for alloys of magnesium and thallium from which Grube and Hille were enabled to draw important conclusions as to mutual solid solubilities of the constituent metals; Grube and Hille resistivity-temperature curves for these alloys containing various amounts of thallium; Grube and Hille magnesium-thallium diagram; and diagrammatic summary of results of investigations of McDonald into the tensile properties of rolled thallium-magnesium alloys containing thallium up to 16 per cent, and indicating that these alloys possess no outstanding properties commending them for immediate notice as structural materials.

These subjects are illustrated and discussed and data are presented in tables covering: Grube melting point data; Grube analyses of thallium-magnesium alloys; transformation data derived from temperature-resistance determinations; thermal analyses made by Grube and Hille; and mechanical properties of 1.46 per cent thallium-magnesium alloy determined by Haughton and Prytherch. *Light Metals*, June, 1940, pages 157–161, 6 illus., 5 tables.

Age-Hardening Magnesium Alloys. W. F. Chubb. The magnesium-tin system is considered and the equilibrium diagram prepared by Grube is analyzed. Results of micro-examination of a series of these alloys made by Grube is discussed and Grube's work is summarized. Equilibrium diagram prepared by Kurnakow and Stepanow is illustrated and analyzed. Theoretical values are found to be closely approached. Melting point data of Kurnakow and Stepanow are given with a description of the microstructure by these investigators. *Light Metals*, July, 1940, pages 169–171, 2 illus., 5 tables.

Beryllium and Some of its Aluminum Alloys. C. B. Sawyer and B. Kjellgren. Beryllium added to magnesium-base alloys containing 8 per cent of aluminum, is said to decrease grain size, to hinder oxidation while melting, and to increase the resistance to corrosion by sea water. This latter effect, with amounts even so small as 0.005 per cent beryllium, may be extraordinary. Similarly beryllium in amounts from 0.005 to 0.6 per cent may be used for grain refinement in aluminum-base alloys. Properties and uses of the pure metal and of some of its alloys are considered including: results reported by J. B. Johnson of Wright Field on castings; results of tests of forged beryllium; the Be-Al alloys and results reported by J. B. Johnson; the Be-Mg alloys; and some applications of beryllium. One table shows results on the Be-Al alloys, reported by J. B. Johnson, and another physical constants and properties of beryllium reported by Losano, Sawyer-Kjellgren, and the 1939 A.S.M. Handbook. *Metals & Alloys*, June, 1940, pages 163–167, 11 illus., 3 tables.

Electro-Plating Practices for Zinc Alloy Die Castings. E. E. Halls. Need for protective finishes; main cleaning; polishing or grinding; cleaning prior to plating; direct nickel-plating procedure; copper-nickel plating; chromium plating; barrel plating; and thicknesses of coatings. Tables show: test results on various electroplated zinc-alloy die castings under tropical humidity tests; test results on various nickel-plated zinc-alloy die castings under salt-spray test indicating that direct nickel proved slightly

superior to nickel plate having an undercoat of copper; and test values of average thickness of platings on the specimens used for the durability tests. Tables also are given for cleaning baths, and electrolytes used. *Metal Treatment*, Spring, 1940, pages 39–44, 13 tables.

Magnesium and Its Alloys. F. A. Fox. Effects of zinc, manganese, cerium, cadmium, and tin as alloying constituents in magnesium, sand-casting technique, and effect of superheating are discussed. In the presence of aluminum, magnesium forms Mn-Al compounds, particles of which resemble the cubic manganese particles occurring in Elektron A.M.503. A part of the manganese also goes into solid solution, and even small amounts of the order of 0.3 per cent have a beneficial effect in improving the corrosion resistance of a straight aluminum alloy. Cerium has been added to magnesium in the presence of mnaganese to improve the mechanical and working properties. Work at the National Physical Laboratory and elsewhere has shown that, in conjunction with zinc, cadmium forms a useful wrought alloy, with quite interesting properties. Continued. *Metal Industry*, June 21, 1940, pages 537–540, 9 illus.

Magnesium and Its Alloys. F. A. Fox. Mechanical properties, machining characteristics, and methods of preventing corrosion of magnesium and its alloys are taken up. The corrosion problem is said to be not nearly so real as it is generally considered to be. Chromate bath and the bath used at the Royal Aircraft Establishment are described. One table gives Elektron alloys in general use, their D.T.D. specifications, form, D.T.D. requirements for chemical composition, average mechanical properties, and A.I.D. test bar. Influence of notch form on fatigue strength is illustrated. Concluded. *Metal Industry*, July 5, 1940, pages 7–11, 5 illus.

Special Bronzes for Aircraft. Aluminum bronzes offer many advantages over steel. A very wide range of physical properties is obtainable by changes in composition or by varied heat treatments, to which these alloys are very sensitive. High fatigue limits which are very little reduced by corrosive conditions, retention of strength at high temperatures, higher thermal conductivity, and good antifrictional properties under certain conditions are other advantages of aluminum bronzes over steel. Corrosion-resisting properties are perhaps superior to those of all copper alloys except those high in nickel.

Properties of Hidurax 1 and 2, aluminum-bronze alloys, Hidurax special, and D.T.D. 197 and 164, and Hidurel 5 and 6 chromium-copper alloys of high conductivity, H.C. copper, Langalloy copper, and Admiralty gunmetal are shown in tables. Processes used by Langley Alloys, Ltd., in the manufacture of copper-base ingots, castings, and forgings are briefly described. Applications referred to include: aluminum-bronze stamping for an undercarriage nut; typical Hidurax parts used in the construction of seaplane breeching chassis; and aluminum-bronze and chromium-copper alloys of high thermal conductivity for aircraft-engine parts. *Aircraft Production*, July, 1940, pages 211–212, 6 illus., 3 tables.

American Practice in Fabricating Magnesium-Alloy Sheet. H. W. Perry. American practice in working magnesium-alloy sheet is discussed and data are presented which were supplied by the Dow Chemical Company and the American Magnesium Company. Recommendations are made in regard to forming, rolling and drawing strips, spinning, riveting, gaskets for tight joints, welding ultra-light alloys, machine settings for spot welding, and avoiding buckling difficulties. Diagrams illustrate common faults in riveting and a correctly driven rivet. Tables cover: rivet shear values for single-row riveted structures; bearing values for Dowmetal E sheet; rivet gage-line distances for angles, channels and I-beams; rivet lengths used for various grips; approximate machine setting for spot-welding sheets composed of magnesium, 1.2 per cent manganese, 0.3 per cent silicon, and 0.3 per cent other impurities; and mechanical strength of spot-welded joints. *Light Metals*, June, 1940, pages 143–147, 2 illus., 6 tables.

Testing of Metals

Creep under Combined Tension and Torsion. H. J. Tapsell and A. E. Johnson. Behavior of a 0.17 per cent carbon steel at 455°C. Special combined tension and torsion creep-testing machine designed for the investigation is described. From a ball pivot at the top of the framework of the machine, is suspended a tension bar which is prevented from rotation by the attachment of a cross bar having freedom of movement vertically in slots cut in channels attached to the frame of the machine. Tension bar carries a tubular stainless-steel adaptor and test specimen is held in the adaptor by a split-ring collar. Similar adaptor fits the lower end of the specimen. Keyways cut in the enlarged ends of the specimen fit keys carried in the two adaptors. Axial load can be applied to the specimen through a universal joint and tension bar attached to the lower adaptor. Electric furnace surrounds the specimen, temperature being maintained within ±2°C. of 455°C. Particulars of the steel and form of specimen, and description of test apparatus and experimental work. *Engineering*, July 12, 1940, pages 24–25, 9 illus., equations.

Evaluating the Surface Finish of Metals. J. Guild. Experiments at the National Physical Laboratory have led to the construction of an instrument for assigning numerical values to the surface finish of metals. Instrument is simple in construction and use, and quick in operation. First model is intended for the examination of approximately flat surfaces, such as rolled metal sheets, but it should be possible to apply the principle used to the measurement of cylindrical and other surfaces. Base of the instrument rests on the metal test sheet, a circular opening in the base exposing the area of the sheet to be measured. Some of the light from a small electric lamp, all of which is focused by means of a lens on the exposed part of the sheet, is reflected in a particular direction and some is scattered. The smoother the surface the greater is the first or specularly reflected part, and the less the scattered part. Instrument compares these two portions. Quantities measured are the current produced in a photoelectric cell, built into the instrument, when light falls on it. *Engineering*, July 19, 1940, pages 44–45, 3 illus., 1 table.

Industrial Research—Its Organization, Aims and Scope. W. C. Devereux, High Duty Alloys, Ltd. Various research systems are described, financing of research is discussed, and general outlook in Britain upon the problems of research is compared with that in other countries. Role of research in the development of the light alloy industries is emphasized. *Light Metals*, June, 1940, pag s 153–154, 2 illus.

Millionth-of-Second Radiographs. C. M. Slack, Westinghouse Electric & Mfg. Co. New cold-cathode ultra-high-speed X-ray tube is described which makes millionth-of-a-second radiographic exposures. By its use X-ray motion pictures and the study of internal strains in rapidly moving parts of motors and machinery may be possible, enabling technicians literally to see into rapidly moving opaque objects, or to study the effect of sudden forces on such objects. X-ray tube contains a standard anode, a small oval-shaped metal cathode, and an auxiliary electrode which serves as a "trigger" to start the discharge of electrons when the tube is activated, but which immediately thereafter assumes the role of focusing cup. Trigger element permits the anode and cathode to be separated sufficiently to forestall formation of a low-voltage arc discharge which would prevent production of X-rays. Radiographs show a 0.22 long rifle bullet piercing wood. Short description. Abstract of American Physical Society paper. *Iron Age*, July 25, 1940, page 31, 3 illus.

The Notched Bar Test. O. R. J. Lee. To make the most of the notched-bar test as a check on the quality of various materials, it is concluded that a series of notched bars of varying degrees of severity will have to be employed. Effects of systematically altering each one of the component variables of the notched-bar test in turn are investigated, including: influence of test piece width; influence of notch radius; influence of notch depth and specimen height; influence of testing velocity; load-deflection diagrams; influence of testing temperature; effect of test piece width on the energy-temperature curve; effect of notch dimensions on the energy-temperature curve; influence of temperature on load-deflection diagrams; influence of test piece width and diameter for a 0.5 per cent carbon steel; influence of specimen width; relation of notched bar to tensile tests; and theoretical aspects of notched-bar testing. Results obtained by various investigators are quoted and discussed. *Instn. Mechanical Engrs., Jour. & Proc.*, June, 1940, pages 114–121, 12 illus.

Light Alloy Research. Long detailed description of the new metallurgical research laboratory of High Duty Alloys, Ltd. *Aircraft Production*, July, 1940, pages 227–230, 12 illus.

Welding

Welding of Non-Ferrous Metals. E. G. West. Factors to be considered in assessing the weldability of nonferrous metals are taken up. Applications of gas, arc and resistance welding are discussed with data on fuel gases for welding. Tables give: operating data for the spot welding of various thicknesses of aluminum, Alclad, duralumin, and Elektron; average physical properties of brasses, bronzes, aluminum bronze, cupro nickel, Everdur, tungum, monel metal, Inconel, nickel silver, D.T.D.118 and 259, duralumin, silumin, and MG.7; approximate mechanical properties of these alloys at elevated temperatures; and summarized data for welding nickel. Preparation of edges for welding of aluminum and of copper, and suitability of positions for welded joints in magnesium alloy are illustrated.

Special conditions prevailing during welding, such as mechanical effects, and metallurgical conditions in weld metal and base metal, are taken up, and physical, mechanical, and chemical properties of the metal which determine the suitability of a welding process for the metal are reviewed. Method for welding aluminum, copper, nickel, maguesium alloys, zinc, and lead are discussed. British Institute of Welding paper. *Metal Treatment*, Spring, 1940, pages 11–17, 20, 3 illus., 5 tables.

Paint

Specifications for Aircraft Finishes. M. A. Coler. Army and Navy specifications for aircraft finishes are discussed, particularly with regard to those for engine-cylinder enamels. A brief survey of the situation is presented which was made by the Paragon Paint and Varnish Company from its field experience and from correspondence with the Government authorities and offices. Parts of U.S. Army Specification No. 3-135 (Enamel, Heat-Resistant, for Castings of Aluminum and Magnesium Alloys), and tentative Navy aeronautical specifications are considered. *Aero Digest*, July, 1940, pages 44, 131.

New Line of Aircraft Engine Finishes. Paragon Cylblak, a new air-drying finish is intended especially for cylinders but is also suitable for use on baffles and air scoops. Crane-Ace is a blue-gray enamel for crankcases. Brief reference only. *Aero Digest*, July, 1940, page 172.

Synthetic Resins in Corrosion-Resistant Paints. R. J. Moore. Modern developments in such protection, based on synthetic resins, are discussed, including: properties of phenol-formaldehyde resin coatings in regard to greater speed, durability, water resistance, chemical resistance, flexibility and its retention; rusting of iron and steel; inhibitors in anticorrosive paints; paints; specifications for phenol resins; and uses of modern protective coatings in regard to protection of steel in river and harbor waters, protection of the interior of steel water tanks, marine coatings and spar varnishes, aircraft coatings, and railway, street cars, and buses. *Modern Plastics*, June, 1940, pages 62–64, 96, 98, 100, 2 illus.

Plastics

Will Plastics Displace Metals? H. Chase. Plastics are often used to supplement or complement metals but rarely to take their place. Certain limitations of plastics, strength of plastics, the advantages of requiring no applied finish, and plastics in aircraft are reviewed in a general discussion. *Metals & Alloys*, June, 1940, pages 157–162, 5 illus.

Aniline-Bagasse Plastics. T. R. McElhinney and S. I. Aronovsky. Study described was undertaken to show which of the several factors entering into the production of these plastics was of most importance and, if possible, to find conditions which would result in a molding compound suitable for commercial use. Experimental procedure and results obtained are described in detail. Table gives preparation and tests of aniline-bagasse plastics. *Modern Plastics*, June, 1940, pages 59–61, 88, 90, 92, 5 illus., 1 table.

Permanence of the Physical Properties of Plastics. J. Delmonte. Plastic deformation data for laminated phenolics, polyvinyl chloride acetate, methyl methacrylate, polystyrene, and cellulose acetate are compared. Experimental evidence is presented to show that after a sufficient length of time plastic deformation assumes a constant rate, continuing indefinitely. Dual nature of the molecular structure of plastics is emphasized, in which true elastic deformation may occur, as well as a time-dependent plastic deformation, even at very low stresses. Further data are presented on the shrinkage of various plastics after exposure to elevated temperatures, and the swelling of these materials after exposure to high humidity or water immersion. Loss in impact strength upon exposure to high temperatures is also disclosed for laminated phenolics. Concluded. *Modern Plastics*, June, 1940, pages 65–68, 84, 86, 17 illus.

Rubber

Ameripol—A New Butadiene Synthetic Rubber. New synthetic rubber developed by B. F. Goodrich Company and from which tires will be manufactured, is a butadiene copolymer considered similar to German Buna N, a copolymer of butadiene and acrylonitrile, and Buna S, a copolymer of butadiene and styrene. Ameripol is claimed to be equal or superior to natural rubber in many of its important properties and, when vulcanized, is said to resist swelling in gasoline, or mineral and vegetable oils. It can be handled like natural rubber in compounding, mixing, extruding, calendering and vulcanizing and all operations are practical on standard rubber-working machinery. Few details of the properties, and discussion of production facilities, and economic and political significance. *India Rubber World*, July 1, 1940, pages 47–48, 4 illus. See also *Aero Digest*, July, 1940, page 55, 2 illus.

"Butyl" Rubber—A New Standard Oil Synthetic. Unlike Perbunan, "butyl" rubber is not resistant to oils and greases but behaves like natural rubber in this respect. It is vulcanizable with sulfur, and it is believed that it can be used to replace natural rubber completely in its applications. In many of its chemical and physical properties it is said to be superior to natural rubber. It is a polymer made entirely from petroleum products. It can be compounded, reinforced, and processed in a manner similar to natural rubber using existing rubber manufacturing equipment, and lends itself to extruding as well as milling and molding. Both butyl and Buna rubber will be manufactured by the Standard Oil Company. Few details only. *India Rubber World*, July 1, 1940, page 44, 2 illus.

German Patents Relating to Synthetic Rubber-Like Materials. L. Voge. German inventions of processes of synthetic-rubber preparation applied for during the period 1915 to 1921 are described. Continued. *India Rubber World*, July 1, 1940, pages 45–46.

Rubberlike Properties of Polybutene. W. J. Sparks, I. E. Lightbrown, L. B. Turner, P. K. Frolich, and C. A. Klebsattel. Polymers prepared from butenes at low temperatures resemble rubber in many physical characteristics but differ chemically in that they are essentially saturated. The polybutenes (available commercially as Vistanex polybutene) have not yet been vulcanized by conventional methods. They are inert toward ozone and concentrated acids. Tensile strength, elasticity, rebound, X-ray structure, electrical properties, elastic memory, fractional solubility and mechanical orientation of the higher molecular-weight polybutenes closely resemble those of rubber and therefore appear to be largely independent of orientation due to carbon-double bond-carbon configuration. *Industrial & Engineering Chemistry, Ind. Ed.*, May, 1940, pages 731–736, 8 illus., 6 tables.

Synthetic Rubber. E. W. Emery. Importance of synthetic rubber to aviation, aircraft applications, war importance, companies making synthetic rubber, and the differences between Neoprene, Thiokol, PV A, Koroseal, and Ameripol are discussed. *Aero Digest*, July, 1940, pages 51–52, 128, 2 illus.

Synthetic Rubbers: A Review of Their Compositions, Properties and Uses. L. A. Wood, Bureau of Standards. Varieties of synthetic rubber and their chemical structure; chloroprene polymers; butadiene polymers; organic polysulfides; isobutene polymers; plasticized vinylchloride polymers; comparison of properties of the different varieties of synthetic rubber in regard to densities, refractive indices, indentity periods along the fiber axes, electrical properties, maximum tensile strengths and corresponding elongations, swelling in liquids, aging properties, permeability, combustion, abrasive characteristics, energy absorption, latex characteristics and electrical conductivity; applications of synthetic rubber; and production figures and prices. Long bibliography. *India Rubber World*, July 1, 1940, pages 33–43 and 51, 11 tables.

Bearings

Lead Bronze Bearing Metals. A. Blankenfeld. Methods that have been tried and used in order to obtain uniform distribution of the lead, good adhesion of the lead bronze to the steel backing, and greater strength in unbacked bearings. Translated from Zeit. Metallkunde No. 2, 1939. *Metal Treatment*, Spring, 1940, pages 32–33, 38.

Fuels and Lubricants

A Future Source of Power? Separation of 350,000 lb. of uranium would yield about 2450 lb. of uranium isotope U-235, equal in energy to about 25,000,000 tons of coal. A few pounds of U-235 would provide an airplane with a vast cruising range and would greatly increase the payload capacity, provided that the appliance for the consumption of the element were not too heavy or too complicated. Work carried out at Columbia University is described, and sources of uranium supplies in Belgian Congo, Canada, Czechoslovakia and the United States are mentioned. *Aeroplane*, June 28, 1940, page 862.

Engine Design and Research

Cooling and Cowlings. D. L. Ellis. Foundations on which cooling and cowling systems must be based are considered. First issue—Fixed radiators, the ducted system, throttling, cooling in climb, smooth joining of the cooling stream and free stream behind the radiator and smooth separation of the flow on entry, efficiency in air flow, and duct losses are discussed. Drawings show: manner in which liquid-cooled and aircooled systems have advanced; way in which velocity and pressure of the airflow vary with the exit of a ducted radiator at top speed, during climb, and at take-off; how the flow varies at different speeds with different entries and exists in a ducted liquid-cooled radiator; solution of the problem of stalling of the flow around or in a duct at different flying speeds; and flow through a radical cowling of an air-cooled engine.

Second issue—In order to examine the effect of a loss of energy in the entry on the drag, the flow through the duct is analyzed more in detail. Pressures and drags through the duct system around a liquid-cooled radiator are illustrated diagrammatically. Cowl is of ideal form for high speed. It is shown how pressure distribution works out on an installation in which there is a relatively high suction on the outer front surface of the cowl, and how troubles caused by the boundary layer can be overcome by intelligent design, including stalling of the flow in the entry, method of avoiding the stalling by means of a lip to deflect the boundary layer, and method of bypassing the boundary layer through a separate duct. Regenerative cooling is explained and accessory cooling is also considered. *Aeroplane*, July 12 and 19, 1940, pages 40–42 and 73–75, 13 illus.

Design of High Speed, Two-Stroke Engines. S. Treves. Fundamental differential equation of the exhaust period is developed. Exhaust period is divided into two parts each having its own characteristics—the pressure-equalization period during which the pressure of the burnt gases is reduced to 1 absolute atmosphere, and the gas-expelling period during which the residual burnt gas in the cylinder is forced out. No account is taken of the forces of inertia due to the acceleration of the gases, laws of steady motion being assumed to apply. A differential equation is finally derived between quantities p, V, and t, which combined with another in finite terms, makes it possible to calculate the pressure p of the gases in a cylinder of displacement V at any time t. The mass G of the gases contained in the cylinder at the moment t may then be obtained from another equation given. Diagram of an opposed-piston type of two-stroke engine gives the dimensions and this type of engine and the case of supercharging are considered in the development of the equations. Continued. *Automotive Industries*, July 15, 1940, pages 75–79, 2 illus., 9 equations.

Economic Aspects of Light Airplane Engines. C. T. Doman, Aircooled Motors Corp. Parallel design and development work of two aircooled engines with widely different applications are discussed. Basic designs of both engines are quite similar. Instead of following the usual aircraft practice in any detail, the author points out that it is advisable to use automotive practice and thus to bring about a simplicity in design which is impossible when normal aircraft-engine practice is followed.

Cylinder design of the two engines is discussed and points of similarity are shown. An 80-hp. 176-cu.in. aircraft engine is described, and reasons for the selection of the design for this particular engine over five other designs are given. Use of large-production automotive equipment, such as starters and generators, in light airplane engines is said to effect economies which can never be expected by using the more specialized apparatus which is available for airplane engines only. *S.A.E. Jour. (Trans.)*, July, 1940, pages 284–290, 10 illus., 1 table.

Geared Engines for Light Airplanes. C. H. Wiegman, Lycoming Division, Aviation Mfg. Corp. Among the problems that had to be solved in the development of geared engines of the four-cylinder two-bank horizontally-opposed type was that of high amplitudes of the fourth and second order crankshaft torsional vibration encountered in the operating range. Damping through the use of a Lanchester friction-type damper, the size of which was as large as practical, reduced the fourth-order resonance successfully but increased the second-order amplitudes at comparable speeds in the operating range of the undamped engine. Extremely low amplitudes are obtained through the use of the pendulum-type or dynamic damper. Lower overall dimensions and a greater number of power impulses per minute are advantages of the Lycoming geared engine in comparison with four- or six-cylinder direct-drive engines developing 75 hp. at 2015 r.p.m. Table gives specifications of the Lycoming 0-145 series of direct-drive and geared engines.

One light geared airplane power plant is described which is designed to reduce manufacturing costs and production tooling, and to cover a range of power outputs at efficient propeller speeds. It is predicted that the high-speed, geared engine with its slow-turning propeller will open new fields for the light airplane. Geared engine has superior take-off and climb performance in comparison with the high-speed direct-drive engines of equal power. *S.A.E. Jour. (Trans.)*, July, 1940, pages 301–304, 7 illus., 1 table.

Notes on Methods of Balancing. K. R. Hopkirk. It is accepted as an established fact that, in order to balance a cylindrical type rotor, two planes spaced apart axially are necessary and sufficient for the addition of correcting weights. Three methods are described. In the first it is assumed that no stroboscopic means of measuring phase of vibration is available, and seven runs are required. For the second method, the use of stroboscopic means to determine the relative phase of the vibrations with respect to one another simplifies the work of finding the vectors, and only three runs are required. For the third method, a complete solution is possible by means of measurements of the relative phases only of the vibrations of the supports, the amplitudes of vibration not being measured. Four sets of measurements are required to determine the four vectors taken during five trial runs. To be continued. *Engineer*, July 19, 1940, pages 38–39, 2 illus., many equations.

Project of the Unusual Terms of Articles 1 to 4 of the Fourth Part of the International Regulations on the Minimum Conditions of Delivery for the Airworthiness Certificate. Denomination of the engine; characteristics of the engine operation and aptitude of operation on the airplane; endurance tests of the engine; general conditions; and hemologation on an airplane. *La Technique Aéronautique*, 4th quarter, 1939, pages 161–168, 1 illus.

Two-Stroke Oil Engine. W. S. Burn. A six-cylinder heavy-oil aircraft engine with horizontally-opposed piston and cylinder, which was developed by the author, is described and illustrated. It has a bore of 7 in. and stroke of 12 in. (8-in. bottom, 4-in. top), and an output of 2100 b.hp. at 150 lb./sq.in. b.m.e.p. at 2000 r.p.m. The six- or eight-cylinder engines for the two-stroke opposed type are considered to have a definite balance of advantages. Crankshaft is virtually floating in its main bearings and big ends should be relatively free of wear and tear due to exceptionally large bearing surfaces. Center connecting rods are easily removable without interfering with either crankshaft, or crankcase, through the cylinders as in normal oil-engine practice.

A cylinder design to require a minimum volume and pressure of scavenge air, and an efficient simple and light scavenge pump absorbing the minimum of power to produce the air are essential. The striking improvement in the Jumo Diesel in recent years illustrates the possibilities in this direction. Fuel consumptions and output of the Junkers Jumo engine had been seriously handicapped by the relatively inefficient centrifugal blower, and in the present state of the development of both radial and axial flow blowers, there is a definite incentive to develop the simplest form of piston-displacer type of scavenge pump. Even the most efficient Rolls-Royce blower, said to be 73 per cent, is not as good as can be readily obtained with simple parts from a displacement-type pump, which has an efficiency of 85 to 90 per cent. Possible solutions of the air charging of two-stroke engines are discussed.

Engine described has been designed for the following: to give variable scavenge pressure and supercharge as and when required to suit cylinder conditions without use of large clearance volumes or reversals of flow or manifolds; to avoid extra cranks on the main crankshaft; to keep length of engine to a minimum; to avoid interference with accessibility of main working parts and also to give good accessibility to pump itself, which is separately completely removable; to avoid spoiling the excellent balance of the main engine itself and to contribute to the secondary balance of the latter; and to give a multiplicity of supply so that each cylinder of the engine is almost as self-contained in its air-charging arrangements as the four-stroke type of engine.

In the larger airplanes, it is proposed to remove the usual blower or booster completely, from the main engines, and to drive a low-pressure blower to supercharge the scavenge pump from a variable-speed auxiliary engine located between main engine and wing root. North East Coast Institution of Engineers and Shipbuilders paper. *Automobile Engr.*, May, 1940, pages 153–155, 2 illus.

Altitude and the Aircraft Engine. E. F. Pierce. Typical data pertinent to the effect of altitude and the needed higher speeds, which altitude permits, on the design and development of aircraft engines. Empirical methods of analyzing the engine characteristics are summarized. The effect of various methods of supercharging upon the engine power output and specific fuel-consumption characteristics are illustrated graphically, and basic problems of power output at altitude and the trend of investigation are discussed. Engine power output and supercharging are considered in regard to two speed-any blower ratio, two stage-any blower ratio, application of the turbo-supercharger to the engine, turbo and two speed, and application of the turbo-supercharging to the two-stage engine, which does provide increased altitude performance. Engine minimum specific fuel consumption in level flight, and miscellaneous problems related to altitude operation (accessory drives and reduction gearing) are discussed. One graph gives a comparison of published data on altitude performance of various Wright, Pratt-Whitney, Curtiss and Liberty aircraft engines. *S.A.E., Preprint for Summer Meeting* June 9 to 14, 1940, 27 pages, 14 illus., 1 equation.

An Analysis of the Charging Process in the Two-Stroke Engine. C. F. Taylor. Definitions and indices are suggested whereby the performance of two-stroke engines tested in different laboratories and by different personnel can easily be compared. In the case of the charging process, it is important

to know the amount of fresh charge available in the cylinder for combustion, the amout of charge delivered through the inlet ports, the charging pressure required, and the amount of work expended in charging. In order to evaluate these factors in terms applicable to different engines, quantitative indices are desirable.

Discussion covers: four-stroke engine charging; the two-stroke charging process; the actual charging process; types of two-stroke engines; scavenging efficiency; scavenging ratio; charging ratio; scavenging pressure ratio; scavenging mean effective pressure; supercharged engines; measurement of scavenging efficiency and details of the M.I.T. method; use of cylinder models in predicting the scavenging efficiency of different cylinder designs (steady-flow and intermittent-flow models); pumping losses; and compression ratio. *S.A.E., Preprint for Summer Meeting*, June 9 to 14, 1940, 19 pages, 7 illus., 14 equations.

Design of High-Speed, Two-Stroke Engines. S. Treves. Two-stroke engines for automobile and aircraft use are classified, and the advantages of the different types are described. The three-port engine, the opposed-piston engine, the U-cylinder engine, the U-cylinder engine with cylinders inclined to the plane through the crankshaft axis and the Duesenberg two-stroke racing engine are shown in drawings. *Automotive Industries*, July 1, 1940, pages 19–24, 5 illus., 3 equations.

The Elements of Pendulum Dampers. R. W. Zdanowich and T. S. Wilson, D. Napier and Sons, Ltd. Theory and design of pendulum dampers are discussed, and experiments on a damper for a four-throw-crankshaft direct-driven aircraft engine (probably a Napier engine) are described. Familiarity with torsional vibration principles, in particular with the method of treating an engine as an r-mass system, is assumed. Dynamics of a pendulum damper is treated in a more general way than hitherto, all known types being included. A new method of considering the effects of a pendulum damper when fixed at any point in an engine system is developed, showing that the damper action results in an alteration or displacement of the critical speeds at which the harmonic orders occur. A convenient method is outlined for arriving theoretically at the best design for a pendulum damper, whatever may be its location in the engine system.

As a practical illustration, an account is given of experimental work which was undertaken to test the behavior of a well known aircraft engine when a certain pendulum damper was fitted to the flywheel. A further account of a similar application to a six-cylinder engine is also given. The Geiger torsiograph is described and illustrated with reproductions of torsiograph records. Special forms of pendulums, a note on the estimation of angular amplitudes of pendulums, a numerical solution of nth degree equations, a bibliography, and a short list of the most important patent specifications relating to pendulum dampers are covered in the appendices. *Instn. Mechanical Engrs., Jour. & Proc.*, June, 1940, pages 182–210, 29 illus., 10 tables, 48 equations.

Elliptical Fillets. Means of increasing the strength of shafts. With radiused fillets the reduction in the fatigue strength of shafts is considerable throughout the range of radii normally used. For this reason elliptical shapes have been suggested, these being produced by form tools or, in the case of grinding operations, by special wheel-truing attachments. According to Foeppl, shear stress of a fillet increases inversely with radius of curvature of the respective stress curve. If the radius of the fillet is made equal to the smaller shaft diameter the stress concentration factor becomes approximately equal to 1. An ellipse according to the relation $a/b = 1 + 2.5d/b$ is proposed by Deutler-Harvers. The authors claim that, from no other form of a fillet for a given axial length a can a greater effect be expected. If the length a becomes very small the ellipse has no advantage compared with the radius. Results of endurance tests made with bright steel shafts of 60 kg./sq.mm. maximum tensile strength, a ratio of shaft diameters $d/D = 0.5$, maximum torsional stress of 22 kg./sq.mm. are briefly discussed. Two suggestions for elliptical fillets are compared. *Aircraft Production*, July, 1940, page 235, 3 illus., equations.

Fuel Injection in Oil Engines in Relation to Combustion. G. W. A. Green. Means attempted by the author for preventing the occurrence of secondary injections caused by surges in the delivery pipe are discussed. Basis for selection of fuel-injection equipment to suit a given design of engine is considered in great detail including: combustion chamber; relation of penetration to diameter of orifice hole in the nozzle; number of nozzle holes; selection of the best type of pintle nozzle for a given engine; selection of the right pump in regard to plunger rate, loading figure and nominal injection angle; maximum capacity of an atomizer of a given design in terms of rate of discharge of fuel; and selection of the best release pressures. Concluded. Institution Mechanical Engineers paper. *Engineering*, June 28, 1940, pages 631–633, 3 illus.

Engine, Fuel and Lubricant Testing

A Condenser Type High Speed Engine Indicator. L. C. Roess. Condenser type of pressure pick-up for a high-speed engine indicator has the advantages of simplicity, ruggedness, and frequency response over other types. Troubles from poor stability, low sensitivity, and particularly ignition pick-up, due to the very high impedance input circuit ordinarily required, as well as the use of airplane-type shielding on ignition systems, have been completely overcome by use of a high-frequency (several megacycles per second) "polarizing voltage" in conjunction with a special bridged T-type of balancing circuit. The T-elements of this circuit can be built into the pick-up very simply and ruggedly, thereby eliminating difficulties with capacity changes in the lead wires.

Sensitivity of the circuit is such that very little amplification is required. Frequency response is limited only by the elastic characteristics of the diaphragm. Both pressure-time and rate-of-pressure-change-time cards can be observed and photographed. Wide frequency response of the indicator makes it particularly applicable to the study of knocking combustion. Long description. *Rev. Scientific Instruments*, June, 1940, pages 183–195, 10 illus., 20 equations.

The Effectiveness of the Burning Process in Nonknocking Engine Explosions. L. Withrow and W. Cornelius. Data presented indicate that it may be possible to increase the effectiveness of the combustion process in an engine operating under nonknocking conditions. Thermodynamic charts used were developed by H. C. Hottel and coworkers to determine the fraction of the liberated heat energy that can be accounted for by the pressure developed during the burning period in each of five different explosions. Simultaneously with the recording of the pressures developed in each explosion, high-speed motion pictures of the inflammation process were photographed. Three sets of flame-picture and pressure data were taken while the single-cylinder quartz-window engine was operating on isooctane and two sets of data while it was running on benzene.

Fractions of the liberated heat energy accounted for at the end of the inflammation period in the respective explosions are considered to be estimates of the effectiveness of combustion. Magnitude of the heat losses during the burning period in the five different engine explosions are determined.

Experimental data, including flame pictures, the use of plaster casts to determine fractional volume inflamed in the respective flame pictures, and pressure measurements are described. Effectiveness of the burning process in each of the explosions pictured, the constant-volume method of using thermodynamic charts to determine the effectiveness of combustion, the engine data required for the determination of the theoretical pressure rise due to combustion with the thermodynamic charts, and application of thermodynamic charts to data from the explosion in the first figure are discussed. The constant-pressure method of using thermodynamic charts to determine the effectiveness of combustion is explained, including the energy-balance and volume-balance procedures. The constant-volume and constant-pressure methods of using the thermodynamic charts are compared. The time and rate of disappearance of the heat energy not accounted for by the thermodynamic charts is taken up, including mass increments required by charts compared with corresponding increments obtained from flame pictures, and the apparent rate of energy loss compared with the mass rate of reaction and with the progress of combustion. *S.A.E., Preprint for Summer Meeting*, June 9 to 14, 1940, 38 pages, 9 illus., 5 tables, 7 equations.

Engine Deposits—and the Effect of Some Fuel Additives. J. A. Moller and H. L. Moir. Equipment used and procedure followed in determining ratings of fuels and of engines insofar as they affect or are affected by fuel deposits. Study described indicates that the combustion chamber of any internal-combustion engine, operating under any given set of conditions or under varying sets of conditions, is constantly attempting to attain and maintain an overall equilibrium which is composed of, and is being constantly balanced between, many definitely interrelated and interdependent equilibriums—mechanical, thermal, and chemical. The disturbing of any one of these equilibriums, must be balanced or offset by compensating changes of one or more of the rest of the equilibriums. It is also indicated that the maintaining of the deposition equilibrium at a point which reduces its effect on the overall engine equilibrium, both quantitatively and qualitatively, is desirable, and that the obtaining and maintaining of such minimum deposition is possible by use of the proper quantity of the correct type of additive. *S.A.E. Jour.*, June, 1940, pages 250–261, 31 illus.

Scope of Pure Oil Test Laboratories Broadened. New wing of the Pure Oil Company laboratories has widened the scope of the mechanical testing division, permitting it to concentrate on many special studies. Description of addition to the laboratory, and of the testing equipment and some of the uses to which it will be put. *Automotive Industries*, July 1, 1940, pages 12–17, 11 illus.

A Simple Auxiliary Means for Making Visible the Flow of Cooling Air in Aircooled Engines. H. Berndorfer and H. Thomas. Smoke tunnel for the investigation of flow of cooling air over engine-cylinder models, and some of its applications are described. For investigation of the flow of cooling air on models of aircooled engines, an arrangement was desired which would permit, in a simple and natural manner and at as high Reynolds numbers as possible, the representation of flow conditions occurring in the carrying away of wall heat to the cooling air and the conducting of the heated air to the outside air. Such a test arrangement was developed by the Stuttgart institute of research on motor vehicles.

Smoke tunnel was applied to determining the following: flow over an uncowled cylinder with fins; flow over a finned cylinder with air control; flow ratio for an inline engine with impact-pressure cooling; and model of the exit plates of an N.A.C.A. cowling for a radial engine in the exposure 1:1. Drawings include: layout of the smoke tunnel, and flow and temperature distribution over an uncowled finned cylinder with and without air control. Photographs are given of the smoke tunnel, flow over the uncowled finned cylinder with and without air control, flow over an inline engine with impact-pressure cooling, and exit of air on an N.A.C.A. cowling for a radial engine. *Luftwissen*, April, 1940, pages 101–103, 6 illus.

Status of Fuel Performance Tests in Aviation Engines. R. F. Gagg. No fuel test or comparison at a single power-output level can provide all the information needed to judge the qualities of an engine for take-off operation. The take-off detonation test must demonstrate maximum power output permitted by fuel characteristics and freedom from overheating of the engine. It has been suggested that a series of test runs similar to the cruising rating test but done at increasing power-output values would provide the necessary data. A nearly equivalent result may be obtained by running only the "end points" of the mixture-control runs previously mentioned.

Method is described which requires a skillful tester, but is relatively fast as compared with making complete mixture-control runs. Best attainable fuel consumption for the engine at the chosen operating conditions and when using a normal gasoline which is completely free from detonation is shown in one curve of several given as typical fuel test data for take-off detonation rating. This indicates the extent of future improvement in take-off performance which may be possible. Criteria for cruising detonation rating of fuels are also presented and discussed. *S.A.E. Jour. (Trans.)*, June, 1940, pages 271–272, 2 illus.

Engine Manufacture

New Wright Engine Plant. Short description of the recently-dedicated new addition to the Wright Aeronautical Corporation factory. *Aviation*, July, 1940, pages 50–51, 5 illus.

Plant 2 of the Wright Aeronautical Corp.—A Most Modern and Complete Aircraft Engine Manufacturing Unit. Plant 2 contains 12.4 acres of floor space, was completed in 57 working days, and is already in operation turning out Whirlwind and Cyclone engines. Description of this plant and processes taking place in it, and reference to work carried on in Plant 1. *Aero. Digest*, July, 1940, pages 92, 95, 7 illus.

Pratt & Whitney Expands. J. P. AuWerter. Steps taken by the Pratt and Whitney Aircraft Company in fitting itself into the program of national defense, and the new plants completed are described in great detail. During the past year the company has tripled its engine capacity and by the end of 1940 its monthly capacity will be the equivalent of 12,000 1000-hp. engines per month. *Aviation*, July, 1940, pages 38–41, 116, 118, 17 illus.

The Dagger in Production. Machining operations on the main components of the Napier-Halford 24-cylinder H-type 890/925-hp. engine are described in detail with many photographs of the machining processes, and with drawings of the cylinder barrel, cylinder head, and method employed to insert valve seats into the cylinder head. Test to check the capacity of the combustion chamber is illustrated and briefly described. *Aircraft Production*, July, 1940, pages 213–218, 18 illus.

The Production of Extruded Valves. Hand forging by drawing down the stem and electric upsetting of the head on valves are briefly described, and the extrusion process at present worked out in Britain by Daniel Doncaster and Sons, and introduced from the United States, is described in detail. *Aircraft Engg.*, June, 1940, pages 189–190, 4 illus.

Engines

An Analysis of Certain Characteristics of a Kadenacy Engine. S. J. Davies. The method of tabulating the data on the characteristics of the

Kadenacy engine is explained, tables are given, and evidence deduced from the test is discussed. Satisfactory support is given for the statement, namely: "The basic contribution that Kadenacy has made to engine design is his discovery that, immediately on rapidly opening the exhaust ports of an engine during the expansion stroke, there is, within the first interval of time for a few thousandths of a second, an urge or impulse in the gases within the cylinder to escape very rapidly from the cylinder, leaving behind them a depression." By suitable timing of the admission valve, the new charge is arranged to enter the cylinder behind the retreating exhaust gases. The analysis demonstrates that the so-called "ballistic" exit of the gases is the dominating factor in establishing the conditions leading to the direct charging of the cylinder, in this case from the atmosphere, through the admission port. The kind of interaction occurring between the gases leaving the exhaust port and the external gases is shown and the exhaust organ must facilitate the exit of the gases from the cylinder. This organ must be dimensioned to meet the practical conditions of running, that is, so that the charging will give the necessary order of b.m.e.p. over the speed range desired. Concluded. *Engineering*, June 28, 1940, pages 617–620, 5 illus., 4 tables.

Bristol Sleeve-Valve-Actuating Mechanism. Valve-actuating mechanism employed on the Bristol single-sleeve 7-, 9-, and 14-cylinder aircraft engines is shown in a drawing and briefly described. On the crankpin of the valve-actuating crankshaft is slidingly mounted the inner member of a spherical joint, the outer member of which is rigidly secured to the valve sleeve at the lower end. The two members of the joint are separated by a lining of antifriction material. From La Technique Moderne. *Automotive Industries*, July 1, 1940, page 17, 1 illus.

PARTS AND ACCESSORIES

An Anti-Knock and Carburetor De-Icing Fluid. Anilol is intended for use in aircraft engines and consists of a mixture of aniline oil and various alcohols corrected for pH value. When mixed with motor fuel, each per cent of Anilol is claimed to increase the octane number by from one to three, depending on lead content of the fuel. Octane-control valve automatically supplies the Anilol in the correct proportion at the carburetor air intake when higher octane values are needed such as at take-off. Octane-control valve incorporates an emergency control which serves the purposes of stabilizing engine temperatures and de-icing the carburetor when required. Carburetor de-icing is claimed to be effected much more rapidly with Anilol than by supplying warm air to the carburetor or by use of alcohol alone. Installation of the injection system layout and section of the automatic valve are shown in drawings and described. *Automotive Industries*, July 1, 1940, page 18, 2 illus.

The Guiberson Diesel. P. H. Wilkenson. Guiberson A-1020 nine-cylinder air-cooled radial direct-drive four-cycle Diesel aircraft engine is described in detail with sectional views. Bore and stroke 5.125 × 5.50 in. Displacement 1021 cu.in. Diameter and area 47 × 12 sq. ft. Rated output 310 hp. at 2150 r.p.m. Total weight (dry) 620 lb. Fuel consumption 0.38 lb./hp.-hr. Oil consumption 0.015 lb./hp.-hr. Compression ratio 14:1. *Aviation*, July, 1940, pages 59, 112, 4 illus.

P & W Engines Released for Domestic and Export Sale. Improvements and equipment incorporated in the various series of Pratt Whitney engines which have been released for domestic and export sale are described. A table shows the normal take-off horsepower and r.p.m., military rating for horsepower and r.p.m. and altitude, normal maximum rating, fuel octane number, propeller ratio, shaft spline, dry weight and engine diameter for three Wasp Jr., six Wasp, six Twin Wasp, four Double Wasp, and four Hornet engines. *Aero Digest*, July, 1940, page 79, 1 table.

Aircraft Radio

Panoramic Reception. New method of receiving many stations simultaneously, developed by M. Wallace, is suited to radio navigation, and has been demonstrated at Indianapolis Airport. Radio signals are observed on the screen of a cathode-ray oscilloscope, and receiver is a conventional superheterodyne in every respect except that the circuits of the oscillator and antenna are tuned continuously from one end of the band to the other at a rate of about 60 times/sec. Receiver thus sweeps past the signals present on the band and registers an audio output voltage as each signal is encountered. Description. *Electronics*, June, 1940, pages 14–15, 84, 86–88, 5 illus.

Zero Zero—But Safe. C. H. Maxwell. Requirements of the perfect instrument landing system, and the most difficult element, the glide path are discussed. The C.A.A.'s blind-landing installation at Indianapolis is described with a diagram of the complete installation, and improvements which are needed to perfect it are pointed out. The author believes that standardization can best be achieved by giving first-hand experience in instrument landing to the greatest possible number of pilots flying various types of aircraft. Experience thus gained by the pilots not only would help to crystallize engineering opinion as to necessary further improvements, but also would stand these pilots in good stead when instrument landing becomes a routine procedure on the airways. *Popular Aviation*, August, 1940, pages 12–14, 78, 80, 7 illus.

Aero Radio Digest. Finch Model F-111A radiofacsimile. Lear Avia automatic antenna reel. Westinghouse and Firestone radio-controlled seadrome contact and boundary lights. Taylor Model Port two-way portable aircraft transmitter and receiver unit designed for private pilots. Radio Receptor UHF airport traffic-control transmitters and receivers. Breting Radio Model C-2 "Weather Reporter." Short descriptions. *Aero Digest*, July, 1940, pages 180, 183.

Aviation Radio. D. Fink. New radio control assembly recently adopted by United Airlines as standard equipment for all their transport ships, and Lear Avia motor-driven antenna reel having a number of new features are described. *Aviation*, July, 1940, pages 63, 2 illus.

F. M. D. Fink. Advantages of frequency modulation and how it may be of use to aviation are discussed. Diagrams give essential frequency-modulation receiver wiring, and elementary difference between a-m and f-m waves. A basic frequency-modulation unit, typical f-m receiver and 1000-watt f-m amplifiers in production are shown in photographs. *Aviation*, July, 1940, pages 48–49, 120, 5 illus.

Private Flying and Aircraft Radio. H. W. Roberts. Before the aircraft radio industry can count on selling the majority of private fliers, it must, in addition to good engineering, make every effort to render ownership of aircraft radio by private pilots more natural and less troublesome than it is today. Recommendations are given. *Aero Digest*, July, 1940, pages 80, 83, 132, 3 illus.

Aeronautical Personnel

Decompression in the R.C.A.F. L. Engel. Hundreds of embryo Canadian pilots under the Commonwealth Air Plan are receiving part of their training in an altitude chamber which, in effect, takes them up to 30,000 ft. without leaving the ground. Detailed records of the high-altitude efficiency of each man with and without an oxygen mask, as shown in the chamber, are being kept and will be related to his subsequent Air Force performance. Records will also be used in an investigation to find a means of predicting the ability of recruits to fly at high altitudes. The two-hour "trip to the substratosphere" is made by an average of 16 recruits a day. Men are taught how to use oxygen masks properly, and what to do about rapidly changing altitude with its effects on ears, sinuses and abdomen. The chamber tests are of some influence in determining whether a particular recruit should be permitted to continue flying training or should be kept on the ground. The test run is described. *Flight*, July 4, 1940, page 9.

Physiology and the Pilot. Various aspects of medical problems in flying are discussed in three articles. "Aviation and Medical Research," by J. P. Lawrie, is a summary of the proceedings at recent medical conference held in the United States which covered a variety of subjects dealing with fitness for flying. "Acceleration and the Pilot," by R. Margaria, is a translation of an Italian article (*Rivista Aeronautica*, April, 1940), covering effects of acceleration, positive and negative, on the pilot, and showing a photograph of the centrifuge used in German experiments. "German Acceleration Research," by S. Ruff, gives results of medical research work carried out at the Luftfahrtmedizinischen Forschungsinstituts at Berlin (from *Luftwissen*, February). *Aircraft Engg.*, June, 1940, pages 164–170, 14 illus.

Production and Operation of Military Aircraft

Space limitations in the Journal prevent publication of reviews of all of the many articles dealing with this subject. References to most of those appearing recently will be found below.

PRODUCTION

"Production Forges Ahead," (brief reference), *Flight*, June 27, 1940, page 568; "Aircraft Production," *Aeroplane*, July 5, 1940, pages 10–11, 3 illus.

50,000 Planes a Year—How Much? How Long? T. P. Wright. An air force of 50,000 airplanes should be obtained by the spring of 1944, according to the estimates given, but it will take four to five years to reach a production rate of 50,000 airplanes a year. Production of 500,500,000 lb. of airplanes, engines, and propellers a year, plant requirements totaling 75,600,000 sq.ft. of floor space, a manufacturing personnel of 680,000 persons, and an anticipated annual cost of approximately $3,560,000,000—these are the totals calculated for a 50,000-planes-a-year aircraft industry. An airplane production rate of approximately 2000 a month, or 24,000 a year, can be reached by January, 1943, according to estimates; a rate of 3000 planes a month, or 36,000 a year, can be attained in four years or the spring of 1944; and a rate of just over 4000 planes a month, or 50,000 planes a year, can be realized in five years, or by July, 1945. This means that we will reach our first objectives of an Air Force of 25,000 planes by January, 1943, under the assumption of continued deliveries to the Allies on current contracts, plus substantial anticipated ones—assumed to total 50 per cent of our production—and allowing for 20 per cent depletion in the U. S. Air Force due to operating losses and obsolescence.

Requirements of an industry capable of producing 50,000 military airplanes a year are dealt with. Only the airplane with its engine and propeller are covered, and allowance is not made for instruments, special equipment, or armament. Condition of the industry as of May, 1940, as to floor space, current production rate, direct labor force, production rate under capacity conditions, and approximate backlog are shown in a table. The new 50,000-planes-a-year-program is explained. Four methods of aircraft-industry expansion which have been tried abroad are discussed in detail, including: expansion of existing plant facilities, the so-called license scheme, government operation, and the so-called "shadow factory" scheme with parent company control.

Miscellaneous constants for computing aircraft-production values and quantities are given in one table and another gives the cost of the facilities which must be produced or made available in other industries to accomplish 50,000-planes-a-year production. A grand total of $572,000,000 is anticipated as the cost of new plants fully equipped with machine tools and using facilities for doing the work required. Another table uses the yardsticks and constants of the second table for determining what the proposed program means in terms of pounds of product, square feet of floor space required, direct and indirect labor personnel needed, and costs to be anticipated. *Aviation*, July, 1940, pages 34–37, 98, 100, 102, 6 illus., 4 tables.

AIR FORCES

"The Empire Training Plan," *Aeroplane*, June 28, 1940, page 846; "Britain's Air Arm," *Aeroplane*, June 21, 1940, pages 823–841, 35 illus.; "Our Daily Bread," *Aeroplane*, June 28, July 5 and 12, 1940, pages 858–859, 16–17, and 43–44; "Aeroplanes from America" (brief note), *Aeroplane*, July 12, 1940, page 33; "The Empire Air Training Scheme," *Aeroplane*, July 5, 1940, pages 4–5, 1 illus.; "Canada's Eyes Aloft," *Western Flying*, July, 1940, pages 12–14, 3 illus.; "Civilian Pilots Needed," *Aeroplane*, July 12, 1940, page 46; "Evacuation of the Channel Islands," *Flight*, July 11, 1940, pages 28–29, 3 illus.; "Ulster as an Air Base," by J. M. Spaight, *Flight*, July 18, 1940, page 49; "The Work of the F.T.S.," *Flight*, July 4, 1940, pages 6b-6d, 7 illus.; "Air Force Targets in Germany," *Engineer*, July 12, 1940, pages 27–28, 3 illus.

"Crushing America by Air," by General William Mitchell (reprinted from July, 1929, issue) *Popular Aviation*, August, 1940, pages 10–11, 58, 60, 63, 5 illus.; "Dump for Obsolete Airplanes" (short note), *Aeroplane*, June 21, 1940, page 809; "Henry's Dream," *Aeroplane*, June 21, 1940, page 808; "On the Assembly Line," by Cy Caldwell, *Aero Digest*, July, 1940, pages 47–48, 135; "American Production," *Flight*, July 11, 1940, page 24; "America and the War," by G. Herrick, *Aeroplane*, July 5, 1940, page 6; "The Case for the Airship Today," by C. E. Rosendahl, *U.S. Air Services*, July, 1940, pages 23–24, 38; "Industry to give Defense Planners all Possible Aid," by H. D. Ralph, *Oil and Gas Journal*, July 18, 1940, page 23; "Factories Expanding," *Aero Digest*, July, 1940, pages 139–140, 142, 5 illus.; "Wanted: Training Centers," by C. A. Zweng, *Western Flying*, July, 1940, pages 21–22, 26, 3 illus.

AIR WARFARE

"The Mathematics of the Balloon Barrage," *Engineer*, June 21, 1940, pages 549–551, 7 illus., equations. "Parachute Troops in Modern Warfare," by F. Smith, *Aero Digest*, July, 1940, pages 63, 180, 1 illus.; "Air Blockade—What are its Possibilities and Difficulties," by Captain Norman Macmillan, *Flight*, July 18, 1940, pages 44c–44d; "Troop Carrying Gliders," *Engineer*, July 19, 1940, page 42; "Air Strategy" by Captain Norman Macmillan, *Flight*, June 20, July 4 and 11, 1940, pages 547–548, 6e-6f, and 26–27; "The Formation of German Parachutists," (photographs only), *Les Ailes*, May 23, 1940, page 1, 4 illus.